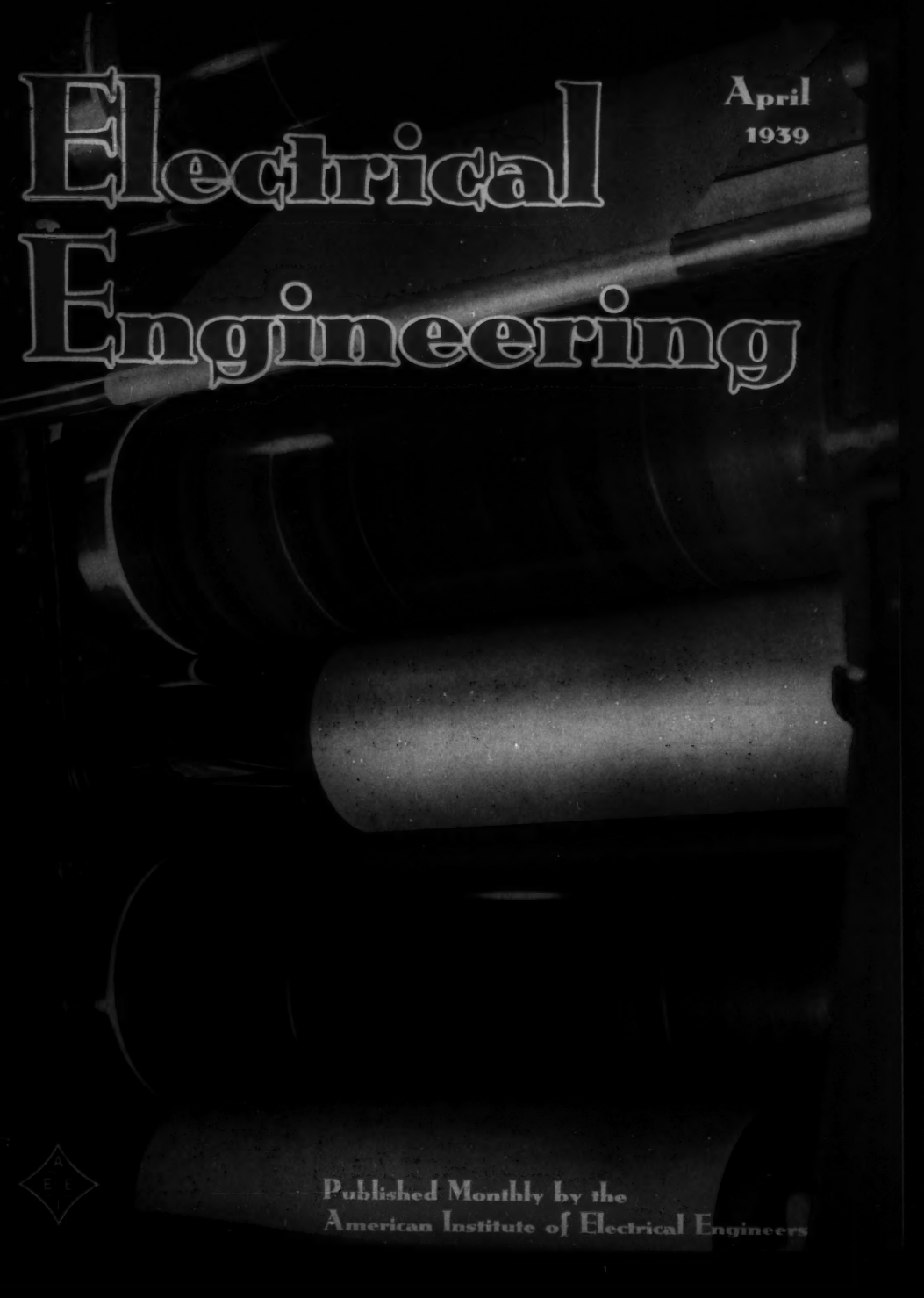
# Electrical Engineering

April
1939



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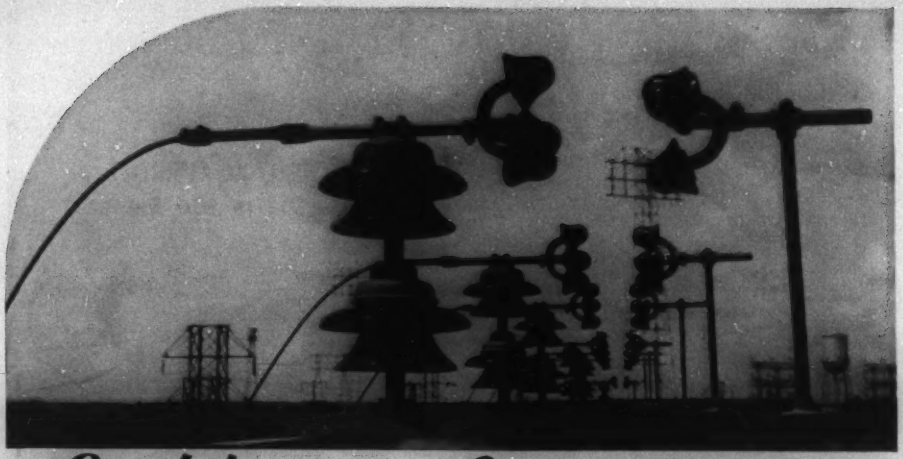
**GENERAL ELECTRIC**

430-140



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# Electrical Engineering

Registered U. S. Patent Office

## for April 1939—

**The Cover:** A supercalendering machine at the plant of the Stevens Paper Company, Westfield, Mass., which may be seen by those attending the AIEE North Eastern District meeting to be held in Springfield, May 3–5. This machine can produce kraft paper, used for making capacitors, as thin as 0.0003 inch. General Electric Photo


| | | |
|---|---|---|
| **Electricity for Treasure Island** | ...W. P. Bear, W. R. Van Bokkelen, and W. Snowden | ...149 |
| **What Is Engineering Experience?** | ...Charles F. Scott | ...152 |
| **Recent Developments in Gearmotors** | | ...154 |
| **The Qualities of a Profession** | ...Vannevar Bush | ...156 |
| **An Exciting and Pleasant 40 Years** | ...F. B. Jewett | ...160 |
| **Members Invited to Visit AIEE Headquarters** | | ...162 |
| **New York World's Fair Will Open April 30** | | ...163 |
| **Standards Activities in AIEE and ASA** | ...H. E. Farrer | ...164 |
| **Evolution of Electrical-Engineering Education** | ...Dugald C. Jackson | ...165 |
| **Some Comments on Graduate Training for Engineers** | | ...168 |
| **News of Institute and Related Activities** *(See next page)* | | ...175 |


### *Transactions Section* *(Follows EE page 190)*


| | | |
|---|---|---|
| **Operation of the Boulder Dam Transmission Line** | | |
| **General Operation of Transmission Line** | ...Wm. S. Peterson | ...131 |
| **Corona Experience on Transmission Line** | ...Bradley Cozzens and Wm. S. Peterson | ...137 |
| **Insulation and Lightning Protection** | ...Bradley Cozzens | ...140 |
| **Carrier-Current Equipment** | ...J. D. Laughlin | ...147 |
| **Transmission Line Relay Protection** | ...L. L. Draper | ...151 |
| **The Electric Strength of Air at High Pressure** | ...H. H. Skilling | ...161 |
| **Generator Damper Windings at Wilson Dam** | ...R. B. George and B. B. Bessesen | ...166 |
| **Reconditioning of Insulating Oils** | ...J. E. Housley | ...172 |



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¶ **Statements and opinions given in articles and papers appearing in "Electrical Engineering" are the expressions of contributors, for which the Institute assumes no responsibility.**

¶ **Correspondence is invited on all controversial matters.**

# High Lights

**Boulder Dam Line.** Operating experience with the Boulder Dam-Los Angeles transmission line during its first $1^1/_2$ years of service is reviewed in a group of five papers presented at the 1938 AIEE Pacific Coast convention. Subjects discussed are the general operation of the line (*Transactions pages 131–7*); corona experience (*Transactions pages 137–40*); insulation and lightning protection (*Transactions pages 140–7*); carrier-current equipment (*Transactions pages 147–51*); and relay protection (*Transactions pages 151–6*).

**Professions.** Aware of possible differences of opinion, a noted educator traces the development of professions from that of primitive medicine men, and finds the common, distinguishing theme of a profession to be ministering to the people; engineering is found to have no single code of principles to guide its social relations, and to need a unity of expression for its professional preservation (*pages 156–60*).

**Summer and Pacific Coast Convention.** Special railroad facilities are offered to eastern members who plan to attend the AIEE combined 1939 summer and Pacific Coast convention to be held June 26–30 in San Francisco, Calif. A feature attraction will be the Golden Gate Exposition; in addition, the committee is making arrangements for extensive entertainment, sports, trips, and recreation (*pages 177–8*).

**AIEE Members Invited.** Invitations have been extended to AIEE members to participate in the following meetings: world automotive engineering congress (*page 178*); international conference on large high-voltage systems (*page 179*); Paris television symposium (*page 179*); a symposium on temperature and its measurement (*page 180*); and an international congress of mathematicians (*page 180*).

**Generator Damper Windings.** Recent investigations and tests have indicated that, in addition to reducing oscillations and improving system stability, damper windings are very effective for reducing high peak voltages in water-wheel generators during unbalanced short circuits. Damper windings may be added to machines already installed (*Transactions pages 166–71*).

**Electricity at the Fairs.** Special substations and distribution systems have been built to supply the electric energy needed to operate the New York and San Francisco 1939 World's Fair. Featuring the first large-scale application of fluorescent lighting, both expositions depict the striking progress achieved in electrical illumination during the past few years (*pages 149–51; 163*)

**Electrical-Engineering Education.** The term "engineering education" appeared for the first time in an Edison Medal citation when the 1938 medal was awarded to Past President Dugald C. Jackson. In his response at the presentation ceremonies, Doctor Jackson discussed some of the early history of electrical-engineering education (*pages 165–8*).

**An Exciting 40 Years.** In accepting the 1939 John Fritz Medal, Past President F. B. Jewett paid tribute to his many associates of the Bell telephone system, with which he has been associated for 40 years, and to the wisdom of those who 50 years or more ago had great visions and created the pattern of the Bell System (*pages 160–2*).

**Reconditioning of Insulating Oil.** In order to maintain its dielectric strength, insulating oil used in transformers and other electrical apparatus must be reconditioned periodically. Activated alumina has been found useful in removing acid from the oil, which is one of the products of deterioration (*Transactions pages 172–6*).

**Graduate Training.** In the March issue appeared an article challenging the necessity or usefulness of ordinary present-day graduate courses in engineering. Representative industrialists and educators see value in this type of training in some situations (*pages 168–74*).

**Student Page.** "The request of those members of the Institute who have been asking for a 'student page' or section in ELECTRICAL ENGINEERING has been granted manyfold," says the current chairman of the AIEE committee on Student Branches in a "Letter to the Editor" (*pages 181–2*).

## News . . . . . 175


AIEE North Eastern District Meeting . . . . . 175
Two Districts Announce Branch Paper Awards . . . . 176
AIEE 1939 Summer and Pacific Coast Convention . . 177
AIEE Executive Committee Meets at Headquarters . 178
Institute Members Planning Trips Abroad . . . . . 178
American Engineering Council . . . . . 180
Engineering Foundation . . . . . 181
Future Meetings
AIEE . . . . . 176
Other Societies . . . . . 180
Letters to the Editor
The Student Engineer and "Electrical Engineering" . . . . . 181
The Paradox of Social Progress . . . . . 182
Technical Progress and Social Development . . . . . 182
Personal Items . . . . . 183
Membership . . . . . 186
Engineering Literature . . . . . 189
Pamphlet Copies of Papers Available . . . . . 190
Industrial Notes . . . . . (See advertising section)
New Products . . . . . (See advertising section)
Employment Notes . . . . . (See advertising section)
Officers and Committees . . . (For complete listing see pages 397–401, September 1938 issue)


**District Meeting.** Power transmission and distribution and industrial power applications are the principal topics to be discussed during the technical sessions of the AIEE North Eastern District meeting to be held May 3–5, 1939 at Springfield, Mass. Plans for the meeting are nearing completion (*pages 175–6*).

**Engineering Experience.** Young engineers who are eager to qualify for legal recognition as "professional engineers" may find helpful the views on "qualifying experience" expressed by state registration examiners (*pages 152–3*).

**Electric Strength of Air.** Experiments show that the dielectric strength of air increases with pressure up to a "critical" point. The form of the electrodes was found to have an important bearing on the results (*Transactions pages 161–5*).

**Gearmotors.** Combination in one unit of an electric motor and speed reducer produces a compact machine which may be thought of as a slow-speed motor, available in a wide variety of standard ratings and motor types (*pages 154–5*).

**An Invitation.** AIEE members planning to attend the New York World's Fair are invited to visit Institute headquarters and take advantage of the facilities provided there for members (*page 162*).

**Electrical Standards.** With its technical committees covering practically every aspect of electrical engineering, the AIEE has an ideal setup for the development of electrical-standards material (*page 164*).

**Coming Soon.** Among special articles and technical papers undergoing preparation for early publication are: an article offering suggestions on seeking employment, by C. F. Dalziel (A'33); an article on the utilization of heat from the sun, by C. G. Abbott; a paper on dielectric breakdown in compressed gases by A. H. Howell (A'35); a paper on bus protection by the AIEE relay subcommittee and the Edison Electric Institute electrical-equipment committee; a paper describing a study of the performance of the 3,600-horsepower New Haven Railroad electric locomotives by Felix Konn (M'32) and F. H. Craton (M'38); a paper describing the Permatron, a magnetically controlled industrial tube, by W. P. Overbeck (A'39); a paper on continuous processing for automobile tire fabrics by G. E. Cassidy and W. A. Mosteller; a paper reporting the results of a study of the benefits of secondary versus primary capacitors by F. M. Starr (A'30); a paper describing the crossbar dial telephone-switching system by F. J. Scudder (M'25) and J. N. Reynolds; and a paper on copper-oxide modulators in carrier telephone systems by R. S. Caruthers.


Subscriptions—$12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain, Spanish Colonies; $13 to Canada; $14 elsewhere. Single copy $1.50. ¶ Address changes must be received by the fifteenth of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge. ¶ ELECTRICAL ENGINEERING is indexed annually by the Institute, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London).


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# Electricity for Treasure Island

*Featuring widespread use of fluorescent lighting, the Golden Gate Exposition is a symbol of the marked progress in electrical illumination achieved in recent years*

By WILLIAM P. BEAR
MEMBER AIEE

WILLIAM R. VAN BOKKELEN
MEMBER AIEE

WAYNE SNOWDEN
ASSOCIATE AIEE

TREASURE ISLAND is 400 acres of sand pumped out of San Francisco Bay; but those attending the combined summer and Pacific Coast Convention of the AIEE to be held in San Francisco, June 26–30, 1939, and other visitors to the Golden Gate International Exposition, will remember it as a scene of rare, colored beauty. Electricity will have been responsible for that. Electricity is what makes the San Francisco Fair different from those that have gone before. Treasure Island is a symbol of the progress that has been made in illumination in just a few short years.

Electricity reaches Treasure Island by way of three 500,000-circular-mil three-conductor 12-kv submarine cables from Oakland and San Francisco. The Pacific Gas and Electric Company meters the energy on a demand-plus-energy basis to the exposition company. Point of delivery is a 16,000-kva substation located in a corner of one of the permanent airplane-hangar buildings on the island. This is augmented by a second substation of 4,000-kva capacity, which serves the Gayway, or amusement zone. Present demand at the fair is over 12,000 kw, but this is expected to reach at least 16,000 kw as the exposition gets into full stride.

First transformation is from 12,000 to 4,000 volts through four 4,000-kva three-phase units, each of which is provided with tap-changing-under-load equipment. From the main substation, 15 feeders, each a four-kilovolt four-wire star-connected circuit with grounded-neutral grid system, and each capable of carrying 1,500 kva, provide primary distribution to 43 transformer vaults located throughout the grounds. Fifteen of these vaults contain a second bank of transformers used for decorative lighting only and fed directly from the substation over special four-kilovolt feeders, as noted later. Four vaults also contain banks for 480-volt service for fountain pumps. Four more feeders originate out of the Gayway substation. Feeders are laid in trenches, covered with redwood plank, and each consists of three number 4/0 40-per cent rubber, tape-and-braid-insulated conductors. Neutrals are bare. Lengths of duct are employed where feeders pass under roadways.

Principal reason for the selection of radial distribution was that switching could be simplified. To minimize the effect of a possible outage on one feeder, adjacent transformer vaults are connected to different feeders. Thus the effect of an outage would be scattered, and one whole section would not "black out."

Transformer banks are three single-phase transformers, 2,400/120 volts, connected wye-wye with common neutral. This system was adopted on account of the predominance of lighting load. Taps are taken off the feeders to supply the transformers through oil cutouts. The secondary distribution for decorative and general lighting purposes is four-wire 208-120 volts.

Most of the decorative lighting is served over four four-kilovolt feeders, exclusively for this purpose, so that con-

WILLIAM P. BEAR is illuminating engineer for the Pacific Gas and Electric Company, San Francisco, Calif. WILLIAM R. VAN BOKKELEN is chief of the division of electricity, 1939 Golden Gate International Exposition. WAYNE SNOWDEN is engineering editor of *Electrical West* and Pacific Coast editor of *Electrical World*, San Francisco.

trol is centered in the main substation. The street lighting is a 6.6-ampere series system, employing ten circuits including one sodium-vapor-lamp circuit. Four circuits emanate from the substation and the others cascade off of them. The 208-120-volt decorative-lighting circuits are extended to fused disconnecting panels near the loads, from which points they are connected to 12,000-watt circuits (35-ampere four-wire) by open wiring on racks or railings.

Most of Treasure Island's main exhibit palaces are long and narrow. Distribution of low-voltage all-purpose energy throughout palaces of this shape lent itself to a scheme wherein three physically parallel "busses" were run the length of the palace, and individual services tapped from these.

Throughout, the wiring has been kept quite simple, a procedure that is consistent with the temporary nature of the installation. Use of first-class materials, however, was considered to represent best economy for gaining high reliability through this simple scheme.

**Palaces facing the Court of Reflections are illuminated by pink fluorescent lamps. Cambodian lighting standards flank the walks**

What makes Treasure Island electrically spectacular, and significant, is the first widespread use of fluorescent tube lamps. More than 2,300 of these lamps, each of 15-watt rating, are used for floodlighting. Colors employed are blue, pink, green, and gold, and for the most part the units are mounted in trough reflectors and concealed behind shrubbery and setbacks, or in niches and windows, and used for the exterior decorative lighting of the inner courts.

The startling color effects that are typical of the San Francisco fair are achieved by the ingenious use of these fluorescent units in conjunction with ultraviolet radiation and fluorescent paint, with high-intensity mercury lamps, and with standard floodlights employing color filters.

Dimensions of the lighting installation can be judged from the fact that for spectacular outside lighting alone 8,000 Mazda floodlighting units are employed in addition to the 2,300 fluorescent tubes. These figures do not include the ultraviolet or mercury-vapor units. To this total load should be added 225 kw which is required for lighting streets, roads, and lanes. Street lighting consists of the 6.6-ampere series Mazda installation on the island proper, with a sodium-vapor installation on the roadway constituting the approach by land. (Treasure Island may also be reached by ferry—the only way except for those traveling by automobile.)

The character of Treasure Island lighting was dictated by the architecture, which follows a Mayan theme. While this is far more ornate than the style that might be termed "modern," it embraces several characteristics of modern architecture—such as the use of large surfaces and an essential simplicity of fundamental forms—yet presents sufficient detail to forestall any impression of its being stark. It is angular rather than curvilinear and is suggestive of Oriental designs. Thus the architecture presented illuminating engineers with large surfaces to be illuminated as well as with ornamental areas which afforded endless opportunities for contrasts in intensity and color.

An example is the Court of the Moon, perhaps the most spectacular lighting achievement of the entire fair. The main impression is of deep blue-violet and brilliant blue, hard to imagine and harder to compare, because nothing like it has been seen before. In the grills and tower caps this is contrasted with rose, while at the center of the court the whole is brought into color balance by means of goldlighted jets of water which arch into the central pool.

This effect was achieved somewhat as follows: To obtain sufficient blue intensity to cover the large wall areas (450 feet long by 80 feet high) both fluorescent and Mazda units were employed. The Mazda units consist of floodlights with 500- and 1,000-watt incandescent lamps and blue color screens. These are installed at ground level, concealed behind a low retaining wall and shrubs.

The fluorescent units, also blue, are similarly placed. As elsewhere at the fair, the fluorescent tubes are mounted in individual troughs, designed for low cost and constructed of aluminum covered with glass. Each trough is supported on its own base which consists merely of a piece of board. This arrangement permitted shifting the fluorescent units in relation to the Mazda units until the desired effect was obtained.

According to estimates, to have floodlighted the Court of the Moon with Mazda lamps alone would have required six times as much energy as is consumed by the combination. Fluorescent units are used to illuminate the lower portions of the walls and Mazda floodlights to reach the upper portions. Where the illumination is most uniform, that is, along the unrelieved surfaces 80 feet high, the ratio between types of units employed is about one fluorescent to two Mazda. The rose color is achieved very simply by the use of pink fluorescent tubes.

The fountain jets are illuminated from below by underwater floodlights using amber color screens. The underwater units here, as throughout the exposition, are mounted on small movable concrete blocks and are fed through rubber-covered cord. This arrangement provided flexibility

for proper placement of the units initially and is considered to afford a permanence consistent with the length of service. The 400-watt mercury-vapor units which illuminate the trees are set in the ground.

Situated in the midst of San Francisco Bay, Treasure Island is a spectacle to those who view it from a distance, as well as to those who are on the island itself. This was no chance occurrence. The lighting was planned to produce beauty from both perspectives, and this was no small problem for illuminating engineers.

Central architectural feature from both far and near is the 410-foot Tower of the Sun. The plaster surface is a light sand color. To cause the tower to stand out when viewed from a distance, and to achieve a gradation of hues ranging from rich amber at the bottom to light amber at the top, eight lighting banks were located on the roofs of surrounding palaces, each bank serving to illuminate one longitudinal segment of the tower. Each bank consists of six 1,500-watt clear Mazda searchlights and three each of amber and clear 1,000-watt Mazda floodlights.

Near the bottom and again near the top, the tower is arched. Interior surfaces exposed by these arches are easily subject to decorative treatment. This could be achieved only with illumination of considerable intensity since the exterior surface, with which the arches had to contrast, was already subject to illumination at a comparatively high intensity. Hues employed are red and deep amber. To obtain these, the following units were employed: 48 1,000-watt amber, and 136 500-watt red and amber. All Mazda floodlights are concealed in niches of the tower. At the top of the tower is a great gold bird, a phoenix 22 feet high, lighted from below by means of eight 500-watt red spotlights.

In contrast to the high intensities required for decorative effects upon the tower are the striking contrasts achieved elsewhere by means of a single fluorescent tube. For example, in the Court of Reflections (which derives its name from the fact it centers around still-water pools) the palace walls are illuminated in salmon pink by means of pink fluorescent lights. At intervals along the walls are some octagonal niches about 10 feet in diameter. A single 15-watt blue fluorescent tube serves to illuminate each niche.

Another thrilling combination of effects is achieved in the Court of Pacifica. Pacifica, goddess of the fair, is an 80-foot statue, standing at one end of her court, just in front of a steel, star-studded screen. This screen is built over a light box, and thus appears in silhouette. The light box is evenly illuminated from within by means of concealed floodlights. These are thyratron controlled so that the entire lighted surface is caused to pass through a spectrum of colors, at any given instant all portions of the surface being of the same hue. Pacifica faces a series of fountains in which the water itself appears to be colored, mainly green. Actually, the water is flowing over translucent plastic domes which glow by reason of colored lighting units concealed within, also thyratron controlled.

**A combination of Mazda and fluorescent lighting is used to illuminate in blue the 80-foot-high palace walls in the Court of the Moon**

Standards for lighting streets, walks, and grounds are Cambodian in style. There are many variations, but the following indicates how one type is constructed and is, to a degree, typical of all: Tubular, tapered steel poles are employed. Some are as high as 86 feet. In one type, 40- or 60-watt lamps are supported on wood battens which are strapped to the pole. Around the poles, functioning like transluscent "lamp shades," are Glyptol-treated canvas tubes (cylindrical housings) supported on metal rings and fastened up the back with a "zipper."

Lighting is the big show at the San Francisco exposition and to electrical engineers is both a recreation and a study. It must be seen to be appreciated. Lighting methods can be described, but no words can describe the effect, which of course is the only aim.

The electrical plans were engineered by the exposition's division of electricity, of which W. R. Van Bokkelen is chief. The substations, distribution system, transformer vaults, and outdoor decorative lighting were installed by the electrical staff of the exposition under supervision of G. E. Garthorne, assistant engineer. Interior wiring was installed by electrical contractors. The General Electric Company acted as consultants and designers of the decorative and spectacular lighting. A. F. Dickerson, manager of the illuminating laboratory and lighting sales at Schenectady, N. Y., supervised this work.

**Changing colors silhouette the screen behind Pacifica. The water of the fountain flows over a translucent dome**

# What Is Engineering Experience?

By CHARLES F. SCOTT
HONORARY MEMBER AIEE

**Young engineers entering the "school of experience" may find pertinent suggestions in the views of state registration examiners as presented to the National Council of State Boards of Engineering Examiners in a recent report on "Qualifying Experience" which forms the basis of this article.**

SAID a young applicant to the secretary of a state registration board: "I don't understand why your board refuses to grant me a license as a professional engineer. Your requirements are a diploma and four years of experience. I have a diploma and five years' experience, but you turn me down. Why is it?" The reply of the secretary opened the eyes of the applicant. "You have been doing routine work which has not added to your professional development," he said, "your experience is not 'satisfactory to the board.'"

Arbitrary as this reply may appear, the secretary was fully justified in making it as the phrase "satisfactory to the board" is part of the wording of the law. If, therefore, so definite—or indefinite—a phrase is to be found in the law, it is fitting that the registration boards should undertake an interpretation.

What kind of experience, then, is "satisfactory to the board?"

The National Council of State Boards of Engineering Examiners has been studying this question, and received at its meeting in October 1938, a report from its committee on qualifying experience, of which the writer was chairman. The report, "Presenting a Situation: Not Attempting a Definition," was a composite of contributions by members of registration boards; it had been submitted for criticism to members of the boards in some 40 states.

The young man looking forward to an engineering career and to professional recognition in which his experience record will be scrutinized by his engineering-society admissions committee and his registration board, will find much that may be helpful in the significant portions of the report which are here presented.

## The Experience Period

The experience period following graduation is a vital factor in the career of the individual engineer and in registration procedures. *To the recent graduate* this experience period is the opportunity for practice in using the knowledge and training of the past in laying the foundation for a future career.

*To the engineering registration board* the reaction of the applicant to the test of experience indicates whether the man has the qualities the professional engineer should have. It indicates his intellectual habits and attitudes, his methods of thinking and doing, his facility in combining theory and practice, his ability to handle new problems, to visualize, and to plan, his capability to develop as shown by the use he has made of opportunities for self-development. From the record of what he has done and how he has done it the board has the best basis for projecting his performance curve into the future, as indication of his competency to practice professional engineering.

## The Model Law

State engineering-registration laws usually are based upon a model law prepared by and recommended by a number of the national engineering societies. According to the model law, "the practice of professional engineering . . . includes any professional service . . . wherein the public welfare or the safeguarding of life, health, or property is concerned or involved, when such professional services require the application of engineering principles and data."

It defines a "professional engineer" as " . . . a person who is qualified by reason of his knowledge of mathematics, the physical sciences, and the principles of engineering, acquired by professional education and practical experience, to engage in the practice of professional engineering." Hence the qualification involves the combination of knowledge and experience.

Normally, according to the model law, the requirements for registration are an acceptable diploma and a "specific record of an additional four years or more of experience in engineering work of a character satisfactory to the board, and indicating that the applicant is competent to practice professional engineering." (If there be no diploma a longer experience is required.)

"Four years or more" implies that the length of the period is to be adequate for acquiring the experience. The minimum of four years should be deemed sufficient only in exceptional cases where the experience has been unusually broad in scope, progressively better in character, and notably high in both average and final level.

"Character of experience" implies that some kinds of "experience" are not satisfactory; for example, routine performance which does not invoke the application of technical knowledge and which does not contribute to development of qualities which indicate competency to practice professional engineering. Character means *quality*, not mere *quantity* of experience measured in time (though a minimum is fixed) or jobs, and the quality must indicate competency.

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## Satisfactory Experience

Broadly, character of experience that is satisfactory is that which indicates competency to practice professional engineering, and the "ability to do." Specifically, the following items are pertinent.

The school of experience should be a laboratory for the application of principles to the solving of problems. Knowledge and experience should become integrated so that they interact and produce something far beyond the arithmetical sum of textbook information and the doing of routine tasks.

On the same job one may exercise judgment in directing the work, while another may simply follow plans and specifications to the letter. Again, in design one may use judgment in choice of standards while another may make slavish use of them.

Qualifying experience is not derived from work that does not require or involve the application of engineering principles and theories, although the work itself may require skill and may be necessary in professional activity; for example, ordinary surveying, drafting, mechanical calculations, or routine cost accounting. Acceptable experience must involve the intelligent practical application of the laws of physical science.

Experience should be sufficient in amount so that repetition produces (1) thorough understanding of the principles involved and (2) the development of judgment as to the method of analysis and solution.

Two phases of experience are (1) the actual activities performed and (2) the attitude of the individual and his progressive development in performing them. What he does is of less consequence than how he does it.

There is bound to be a dividing line between those who are indifferent to development and those who are bound to achieve against all obstacles, if professional engineering is to develop on the basis of higher standards.

A progressive advancement in the application of engineering data and principles should indicate that the applicant is capable of taking charge of some branch of engineering work. He should recognize his limitations as well as his ability, and should decline to accept a commitment that he knows he is not qualified to fulfill.

A board should secure details of an applicant's duties and responsibilities by asking such questions as these: What did he do? What engineering data or principles did he apply? What engineering judgment and discretion did he exercise? What was the scope and importance of the project? What is the ability to devise and to plan? What is the evidence of progressive responsibility? What initiative and originality and courage, and what personal force for overcoming difficulties have been shown? What aid to progress has been secured through reading and study, through membership in an engineering society, through correspondence-school or night-school courses?

Obviously, a board cannot rely on titles—they may be very deceptive. Jobs and positions and things done are significant only as to qualities essential to the professional engineer which result.

Practical experience is thus defined in handbook 36 of the New York State board of licensing for professional engineers:

> Practical experience in professional engineering work to be considered to be of a grade and character satisfactory to the Board of Examiners shall be such as to require the intensive application of engineering principles in the practical solution of engineering problems. This work shall predicate a knowledge of engineering mathematics, physical and applied sciences, properties of materials, and the fundamental principles of engineering design. It shall be broad in scope and of such nature as to develop and mature the applicant's engineering knowledge and judgment.

## Supplemental Qualities

In general, registrants who possess administrative ability are eligible for the higher ranks in their profession; they have desirable qualities for making them "competent to practice professional engineering." Administrative ability is, therefore, a desirable though not an essential quality; it may be given consideration in estimating experience as qualifying for "professional engineering" practice.

Professional engineering (as defined in the model law) includes " . . . evaluation, planning . . . in connection with any public or private utilities . . . works or projects, wherein the public welfare, or the safeguarding of life, health, or property is concerned." It seems reasonable, then, to expect more than mere physical competency.

Economic justification and social utility are within the larger engineering perspective. Ability to take this larger view and to co-ordinate many engineering elements in a single project and to adjust it to the environment outside the technical elements, by looking beyond engineering efficiency to social utility and public welfare, is a quality of our outstanding engineers—a quality to be developed through the years. But, if added to normal knowledge and experience a young man gives promise of a larger outlook on engineering and life, the board enjoys a double assurance that it is making a wise selection.

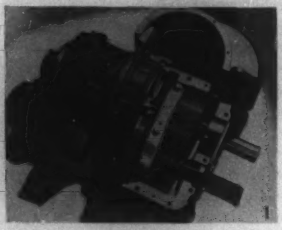
## Registration—
## A New Development in Engineering

Engineering registration in theory and practice is a pioneering effort. Of the 40 states having registration, 90 per cent have not had it more than 20 years and 30 per cent of them have had it less than 4 years. In some states the procedures in licensing are well developed; in others they are just beginning. The National Council seeks to interchange information and unify objectives.

Just as engineering schools and societies and engineering theory and practice progress, so must the goals and the procedures in engineering registration. The evaluation of experience cannot be effected through dogmatic definition; discretion must be exercised in each specific case. The applicant should realize that the true function of technical knowledge and qualifying experience is to produce competency to practice professional engineering. This may seem indefinite and intangible. It is. It cannot be measured by objective yardsticks; there is a human quality involved in interpreting what is "satisfactory to the board."

# Recent Developments in Gearmotors

ELECTRIC motors and other types of prime movers rotate at much higher speeds than do the majority of driven machines and therefore some means of speed reduction is necessary. One of the most important and most efficient of methods is gearing, which satisfies the fundamental requirements of compactness and high mechanical efficiency. With helical gears mounted on antifriction bearings and running in oil, efficiencies of 98 per cent for single-reduction gear drives and 96 per cent for double-reduction drives may be attained. Initial cost is always important in the purchase of power-transmission equipment, and surveys indicate that in the majority of applications the gear transmissions can be purchased for a lower initial cost than can other types of drives. This is also true for slow-speed motors which would form an alternate for the high-speed motor and some form of speed reduction.



Although gears themselves have been in use for many years as a means of speed reduction and power transmission, it was not recognized that there would be a demand for standardized gear drives. Today speed-reducer units and gearmotors for both horizontal and vertical operation are available for a wide range of horsepowers and output speeds. In gearmotors a large variety of motor designs may be had and the user generally can find a standard piece of apparatus for the majority of industrial applications.

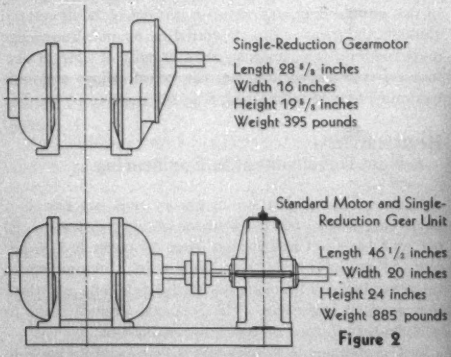
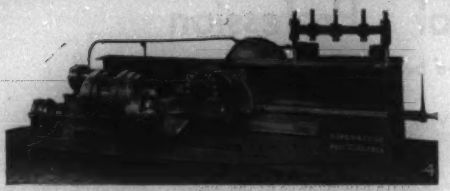



Figure 2

Gearmotors should be considered as slow-speed motors wherein the transmission parts have been so designed that the full torque of the motor during both starting and overload periods can be transmitted without injury to the gearing parts. Various types are available, such as open-type squirrel-cage motors, totally enclosed fan-cooled, and double-reduction gearmotors with speed reductions as high as 40 to 1, and gearmotors with special slow-speed-shaft extensions and with high-speed motor-shaft extensions for the mounting of brake parts.

Much thought has been given on the part of gearmotor designers to the type of construction to be used for the gear case and necessary adapter to enable the manufacturer to use standard motor frames which are brought through the shop in quantities. For gear ratios higher than approximately nine to one, a type of construction is most generally used wherein the supporting feet are a part of the gear housing and a round-frame motor is used, supported from this same housing. Figure 1 illustrates this type of construction. The split-case construction also provides ease of assembly and dismantling and the gear ratio may be changed quickly either in the factory or in the field. In the design of the gear case, special attention is given to the adequacy of the bolts, for the torque at the output shaft of the gearmotor is the torque developed by the motor parts multiplied by the gear ratio. Adequate support is also necessary for overhung loads where the connection to the driven apparatus is through a belt drive,

Abstract of a paper delivered before the AIEE Springfield Section on September 12, 1938, by R. S. Marthens, manager of the gearing division of Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.



chain drive, or open gearing. Close co-operation is required between the gear designers and the motor designers to provide the proper mechanical parts for transmitting the developed torque.

In many respects the type of construction for industrial speed-reducers built as separate gear drives and gearmotors is identical. In both, lubrication is a relatively simple

problem, because the same oil may be used for both the gears and the bearings. The difference in space and weight for gearmotors and coupled-type speed reducers is illustrated in figure 2. This example is a 15-horsepower 1,750-rpm set of motor parts combined with speed-reducer parts which provide an output speed of 350 rpm. The gearmotor shows a saving in length of 38 per cent, in width 20 per cent, in height 18 per cent, and in weight 55 per cent. Also, a saving is obtained in the price of the gearmotor.

A general survey of industrial applications indicates that approximately 80 per cent of all motors one horsepower and above are connected to the driven machines through some form of speed reduction. An application of gearmotors where a compact drive is necessary is illustrated by figure 3. Here two gearmotors are used to drive a winder in a paper mill. The center distance on the driving rolls is such that the usual type of drive could not be used. These gearmotors employ wound-rotor induction-motor parts combined with a single reduction in the gearing parts of approximately five to one. When a single reduction of external helical gears is used, the output shaft is offset from the motor shaft. The gear case has been so designed that it can be rotated on the motor frame and the output shaft may be in any one of four positions. By choosing two of these positions and staggering the motor frames, this compact drive is obtained.

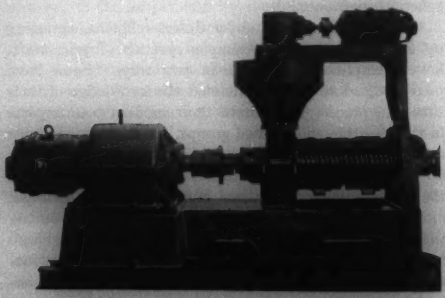
A machine tool application is illustrated by figure 4, which shows a 15-horsepower single-reduction gearmotor applied to a metal-cutting saw. Four output speeds are obtained by the use of four-speed induction-motor parts.

A special application of gearmotors is shown in figure 5. A 75-horsepower 22-rpm gearmotor is used for this dredge cutter drive and the gearmotor is coupled directly to the cutter shaft. Splash-proof motor parts are used and the oiling system for the gears has been arranged so that the

cutter shaft can operate from the horizontal to a maximum of 50 degrees below the horizontal. The bearings on the output shaft of the gearmotor absorb the thrust from the cutter.

Many gearmotors have been used in conveyor applications where extremely low speeds are required. Such application is illustrated by figure 6; here the gearmotor is mounted directly beneath one portion of the conveyor and only sufficient space is required alongside the conveyor to provide for the chain drive connection to the head shaft.

When very low output speeds are required, together with minimum space, triple-reduction gearmotors frequently are employed. The gearmotor shown in figure 7 is a 50-horsepower unit using general-purpose induction-motor parts and having an output speed of 13 rpm. Vegetable oil is obtained from shale in this expeller-type press, and the gearmotor drive has proved quite satisfactory over an extended operating period. Many geared drives have been in successful operation 24 hours a day, six to seven days a week, for upward of ten years.



# The Qualities of a Profession

## *as outlined in a recent address delivered before American Engineering Council*

By VANNEVAR BUSH
FELLOW AIEE

IN 1937, at Milwaukee, I attempted an analysis of the organization of the engineering profession.* Here I wish to develop that theme somewhat and I intend to trace briefly the relationship of engineering to the other professions, the professional traditions which engineers inherit, and the outlook for the engineering profession in view of its unique relationship to society. I plan to review the history of professions very sketchily; but through this history runs a thread to which I wish especially to direct your attention.

We can start far back, but not tarry long in our review. In every primitive tribe there was some sort of medicine man. He was a man apart, the advisor of the clan rather than its titular leader. He spoke, in his field, with authority, and this rested upon a special knowledge which he was supposed to possess. The medicine man was the progenitor of the professional man of today.

His closest modern counterpart is the scientist. The scientist and the medicine man have much in common. Tribal regalias and feathers have undergone metamorphosis and reappear in cabalistic titles and letters surrounding names. The queer jargon of the cult has changed in nature but preserved its hypnotic effect. Solemn pronouncements about the unknowable still catch the ear of the multitude. The claim to a favored position in society is still based on the occasional ability to unscrew the inscrutable. In fact, one difficulty that faces the scientist is that he may be mistaken for a medicine man; able at will to produce rabbits from hats, instead of the careful, hard-working, human individual he really is.

The descent of the engineer from the medicine man has been highly involved; and it will clarify some obscure relationships if we trace part of it; for there is a central thread which runs through the tale.

The medicine man, and the member of the pagan priesthood which succeeded him, was characterized by numerous attributes. He had a strict code of conduct. He trained neophytes, subjected them to a long period of apprenticeship, initiated them into the mysteries, and inculcated in them pride in the cult, and rigid discipline in its formulas. He severely restricted his numbers, by intellectual hurdles to be surmounted. He spoke a special language. He sat as advisor in councils of the mighty. But, more essential than all of these, he ministered to the people.

This was the first professional group, and all others have derived from it. Not every attribute has been maintained as new professions have emerged; but to a surprising extent their counterparts can still be found. In every one of the professional groups, however, will be found the initial central theme intact—they minister to the people. Otherwise they no longer endure as professional groups.

Ministry needs definition for our purposes. The alteration of word meanings with new usages is such that it is only too easy to be misunderstood. Ministry is not service, and we have so completely altered the essential significance of the latter word that it may have utterly different connotations to different hearers. Ministry carries with it the ideas of dignity and authority; it connotes no weakness, and offers no apology. The word has been carried into diplomatic usage; and in the derived form of administer into law and business. There is no fog of subservience surrounding the concept. The physician who ministers to his client takes charge by right of superior specialized knowledge of a highly personal aspect of the affairs of the individual. The attorney assumes professional responsibility for guiding the legal acts of his client, and speaks with the whole authority of the statutes as a background. It is in this higher sense that we trace the thread of ministry to the people.

This is the fuel which has kept alight through many ages the professional spirit. Every time that the fuel has become exhausted, the light has gone out. It has not mattered how much was retained of trappings and mysticism, nor what the profundity of utterances, there has been no true profession that has not with dignity and authority advised and counselled the people, that has not guarded the commonweal. For a true profession exists only as the people allow it to maintain its prerogatives by reason of confidence in its integrity and belief in its general beneficence.

The monastic orders, under divers religions, springing up as outgrowths of the simpler systems of priestcraft, have exemplified the theme in two ways. Some have preserved, adorned, and extended the knowledge of their time and place. These have their modern counterparts in the scientific and learned groups, the custodians of our culture, and the source from which flows new knowledge for the use of man. Other orders carried to great heights the direct ministry to those in misfortune or distress; often at great self-sacrifice, as did the early Jesuits among the Indians of our west. Both forms have remained high in the esteem of the people and have endured. Occasional groups have lost the thread, and have, for example, be-

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An address delivered at the "All Engineers' Dinner" of American Engineering Council, Washington, D. C., January 13, 1939.

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*"The Engineer and His Relation to Government," delivered at the AIEE summer convention, Milwaukee, Wis., June 22, 1937, and published in the August 1937 issue of ELECTRICAL ENGINEERING, pages 928–36.

come militant orders devoted to self-aggrandizement; and these have disappeared.

## The Teaching Profession

Out of the early priesthood came also the teaching orders, whose ministry took the form of instruction of the young, and this aspect of professional activity is represented today by the great profession of teachers everywhere. This group has little indeed of the trappings of the medicine man, it has no single closely knit aggressive society representing it; its language is becoming complicated but is still fairly intelligible to the layman. Where it has maintained its ideals it is honored and respected. Great teachers do not find riches heaped upon them, they do not become affluent. Great teachers have no interest in riches. In the great teacher the parental instinct, which is so often at the basis of senseless extremes of individual striving for wealth, becomes sublimated into a broad love of youth which calls for neither wealth nor power for its enjoyment and satisfaction.

## The Medical Profession

A very early offshoot was the profession of medicine, for ministry to the ill was a primitive need. It has had a long and distinguished history. Utilizing the fruits of science it is today in full tide of accomplishment for the benefit of mankind. It has had vast power and influence. Yet, today, in the United States, it is at a turn of the road, and its most thoughtful members are giving earnest consideration to its future. There is serious danger that its light may fail, and its heritage of idealism may be lost.

The profession of medicine, by reason of its very nature, has preserved many of the attributes of the ancient forms. It selects its neophytes by rigorous intellectual elimination, trains them over many years, and seeks to endow them with the philosophy of their profession. It severely restricts its own numbers, perhaps too severely in view of the task before it. It preserves itself apart, by special language, and has a unique code of conduct. It has sat in the councils of government and advised. By the will of the people it has been given special privileges and prerogatives for use in pursuit of its objectives. It is highly organized.

Through long ages it has held well to its ideal of simple ministry to the people, and has disciplined under its codes those who would use its special privileges for other ends. It has guarded the people against their own folly, and has been properly militant in maintenance of its sphere of the public weal. Its individual members are in general respected in their own communities to an extraordinary degree.

Yet, in these days when all institutions are undergoing scrutiny, when our population in fear and distress is prone to be critical, there is evidence about us that the profession, as a profession, does not command that full support of the people of the country without which it cannot continue on the path. Yet as one looks about in the medical profession signs are seen of a resurgence of idealism, a re-emphasis on the simple mission of healing, and a recognition of the central theme of ministry to the people. This I am convinced is the true motive of the great majority of the members of this grand profession. Yet there is much suspicion in the public mind that aggrandizement, utilization of power for the professional advancement of the membership, the guild spirit in its cruder form, are rampant. I second the thought of many eminent members of the profession itself that unless this suspicion is allayed by a revival of simple ideals, the profession will suffer, and the people will suffer enormously with it. It is well that engineers should be deeply interested in the outcome, for medicine is a very ancient profession from which we have much to learn.

## The Legal Profession

To treat the origins of the profession of law, its codes and countercurrents, would require an article in itself. Here is a field in which the preservation of the true philosophy of a profession is intricate indeed. Endowed with special privilege under the law, it largely regulates its own conduct. Never quite successful in the recruiting, training, and indoctrination of its neophytes, its maintenance of adherence to a high code of conduct is rendered more difficult. Counseling with government, and by the nature of its mission, participating directly therein, it has great power for good or evil. It certainly strives, as an organized profession, for the public welfare; but its zeal in this regard is not always such as to cause it to disregard the special welfare of its own group; and the two, withal, are sometimes hard to disentangle. It ministers to those in legal distress with great effectiveness; but the distressed often appear in pairs. It is hardly judged as a whole by the public. Certain it is, however, that those of its membership, on the bench or at the bar, who have risen to the highest positions in their devotion to professional ideals, are respected and honored by the public. Certain it is also, that, should this respect falter, we as a democracy would soon be in a sorry state.

## The Engineering Profession

But our principal concern here is the engineering profession, and we inquire, what is the engineering profession; is it a profession at all; and if it is, will it develop into the full stature to which the importance of its works entitles it to aspire?

It is relatively young. The military engineer appeared in the first steps of the mechanization of warfare, when forts began to take shape. His counterpart in peaceful affairs was called a civil engineer. With the industrial revolution, and especially with the spread of mechanization from the factory into every walk of life, engineering became exceedingly diversified. Applying science in an economic manner to the needs of mankind is its broad field. Its disciplines are spread over all the sciences as they become thus applied, and embrace also portions of economics, law, and business practice which are integral parts of the process of application. It is somewhat loosely

organized as professions go. To a minor extent, only, it limits its numbers; but the very strictness of its essential disciplines provides some selection of its neophytes. Until recently it has done very little in an organized fashion to inculcate in its younger members the philosophy of the profession, leaving this largely to those of its individuals who are also members of the teaching profession. That branch which represents the consultant, and others to a degree, have drawn codes; but there is no body of codified principles which is accepted and applied by the profession as a whole. It has no highly distinct language or jargon, for it must continuously work with laymen.

These are, however, incidentals. The important point is this: Does it have a central theme of ministering to the people? Most certainly it serves the public in myriad ways, but are its individual members activated primarily by the professional spirit of dignified and authoritative counsel and guidance?

## The Business Profession

In order properly to inquire into this weighty question, we need to digress a moment to consider another large group of the population, the modern men of business who have derived from the ancient traders and merchants. The merchant class has not usually been a professional grouping in the true sense; and engineering, which has derived its philosophy from this source as well as from science, naturally partakes of the heritage of both groups. Business has served the public, of course, but its main theme has been the profit motive, a salutary objective when restricted by law to the use of ethical procedures in its pursuit, but not a professional objective.

One of the most encouraging signs of the times is the gradual emergence in our day of the truly professional man of business. Scattered, not organized, with no sign of professional trappings, they are nonetheless possessed of a high mission, which needs only formulation and recognition in order that they may constitute a new and strong profession. This is occurring for one reason because of a gradual change in corporate form. The owner-manager was activated by the profit motive, and no amount of paternalism could wholly alter his position in the social scheme. Even with corporations, the ownership of which is widely scattered, the manager is ordinarily controlled by and primarily responsible to a few powerful owners, so that he in essence still represents the interest of the owners in his relations with the three bodies with which he deals; the government, the employees, and the consuming public. It is his difficult task to reap for the owners' benefit the fruits of his industrial operation; while maintaining at least tolerance on the part of the other bodies. But there are some corporations in which ownership is so diffused that the management becomes in effect a self-perpetuating entity, partaking therefore of the nature of a trusteeship, with equally weighed obligations and responsibilities to all four bodies; owners, employees, government, and consumers. Among such managing groups will be found individuals who have the professional philosophy in high degree, conducting their affairs for the just and equitable benefit of all four groups concerned, maintaining the health and progress of their institutions as potent agencies for ministration to the needs of the people. They find common ground with the trustees of great foundations, of hospitals, and all non-profit organizations devoted to the public welfare. They find common ground also with many of those who make a career of the business of government. Their ranks are recruited by many in the ordinary walks of business who have seen a light; and envisioned a function in life which is higher in its satisfactions than the struggle of any body against any other; namely a struggle with all bodies to preserve an ideal. Out of this trend, as competition for industrial existence becomes tempered, should emerge a new profession with its own traditions and beliefs, which is capable of managing prosperity so that it will be conducive to the health of a nation; and there is grave question whether this objective can be attained in any other way. I wish there were a special order of knighthood in this country to honor and unite those who are now blazing the difficult path and developing the novel philosophy of this new profession.

Engineering, however, derived jointly from the quiet cloisters of science and from the turmoil and strife of aggressive business, and it is no wonder, therefore, that it should wobble a bit as it seeks to evolve its own professional philosophy. Just as it is not reasonable to expect the young neophyte to grasp at once the idealism of his calling, so it is perhaps not reasonable to expect a profession which is so young and which has grown so fast to have found itself in this regard.

## Entrance Into a Profession

The period of initiation into any profession should extend into maturity. Only when members reached the full bloom of manhood did the ancient orders entrust the mysteries to their care. The young neophyte served his apprenticeship under constant tutelage and close guidance by mature minds, and this we still find in every profession. As apprentice, as employee, he is called upon to prove himself; before he enters into that relationship where his opinions are controlling in his special field; and some there are who never emerge from close control and the mere exercise of technical proficiency. In the engineering profession this emergence usually is circumscribed by the fact that most engineers operate as members of industrial organizations of one sort and another, and the fact that they serve their apprenticeship in this same sort of organization and come to devote their entire efforts to its affairs, rather than to enter them after professional recognition elsewhere, as is usually the case with medical or legal individuals. This, however, merely emphasizes the need for better supervision of the neophytes by the members of the engineering profession who have arrived. It is not enough to leave their training to the industrial organizations of which they are junior members. Inculcation of the principles of the profession can come only from those who themselves have attained to a full grasp of its proper function in society, who have arrived at a

balanced judgment as to its responsibility to the several groupings of which society is composed, and who have a professional interest in the young men who are destined to succeed them in the profession. Every profession should have its secrets and its mysteries; spread before the world that all may read, but truly grasped only by those who have lived the professional life; and these should be transmitted to the neophytes with due care, with reverence for their inherent worth, and in due time. Ritual and symbolism, secrecy and circumspection, were the ancient paraphernalias which insured a proper seriousness in youth in order that the impartation might be impressive. These have not wholly disappeared in the modern professions. Admission to the bar, the use of the title of doctor, and similar customs and usages have profound effect in producing a professional consciousness. The engineering profession is wholly without these aids, and its task of inducting its neophytes into the true professional atmosphere is thus rendered doubly difficult.

But does it matter after all? Are the things that engineers do so vital that they must needs be approached in the professional spirit? Most certainly it matters. And most certainly the task is a professional one. The impact of science is making a new world, and the engineer is in the forefront of the remaking. He lights the way in a very literal sense. He brings peoples close together for better or worse, by facile communication and rapid transportation. He guards the food supply, and replaces the hopelessness of Malthus with an embarrassing plenty. He shortens the hours of labor, and fills the consequent leisure with distractions. He temporarily disrupts the techniques of whole industries, and thus alters the life habits of many people, in maintaining a continually rising standard of living. He bores through the earth and under the sea, and flies above the clouds. He builds great cities, and builds also the means whereby they may be destroyed. Certainly there was never a profession that more truly needed the professional spirit, if the welfare of man is to be preserved.

## Expression of Professional Spirit

There is no lack of signs of a rising consciousness in this regard. The profession is most positively vocal. There is a vigorous new organization, linking several large groups, devoting itself to the improvement of the education of the young engineer, and the instillation of high principles during his early career. Engineering literature is full of discussions of the duties and responsibilities of the profession, and out of this may crystallize some day a code, a set of principles of conduct, a guide drawn solely with the object of advancing the public weal, which will become accepted by engineers everywhere, whether in government employ, private practice, or industrial organization. Having, to some extent at least, consolidated their techniques, engineers are certainly giving thought and voice to their position in society, and to their responsibility for the use of the great works which they create.

The focus of this whole affair is the American Engineering Council. More than any other group it represents the engineering profession as a whole, in its relationships with government, other professions, and the public. Here, more than in any other organization, reside the external as contrasted with the internal relationships of the profession. It was founded by men who considered its functions in terms of a high idealism. It is now going through a strenuous period of self-examination. To this every individual can contribute only one set of thoughts to be merged with all of those which seethe, and interact, out of which will come in due time that consensus which will form the opinions, traditions, codes, and consciousness which will mold the engineering profession. It will come unless the Council fails; for if it fails, and if its place is not taken by a more rugged successor, there will be no unitary engineering profession at all. In the spirit of adding my few thoughts to those of the eminent men who are directing the Council I have previously offered comments, and I now comment again, with the expectation that I will be disagreed with and answered, with the wish to add my mite to the consummation.

I find it a vigorous and rapidly evolving body. I consider it to be utterly inadequately supported by the profession as a whole, in comparison with the central bodies of sister professions, and with a serious problem as to how adequate support can be drawn for the great task that lies ahead of it. I find it partaking of the great American tendency toward overcomplication, and inclined to attempt things which seem to me personally to be off the main beat. I find to my great joy that it is gradually becoming known and recognized; and I trust this is just a beginning. I find it guided by some of the best minds in the profession as its officers, who are giving valuable time to its cause; and I hence cannot fail to be optimistic as to its future.

To me, however, there is just one point on which I wish to focus attention. I find it struggling with its own philosophy. I find, in fact, that it hesitates as it formulates its idealism; that it has not yet placed its foot unequivocally and irrevocably upon the path that leads to complete devotion to the public welfare. I find that it has not yet enunciated its belief that the great mission of the engineer lies in intelligent, aggressive, devoted ministration to the people. This I urge with all the emphasis I can command.

## Necessity for a Central Organization

I do not seek to conjure away practical difficulties by ignoring them. I know full well what restricted budgets mean. The argument that the support of the membership can be obtained only if they can see a direct and personal benefit from their contributions has a familiar ring. I recognize that it is entirely proper for professional men to join in an insistence upon a reasonable and proper recognition of their services to society. Yet if there is no central organization which has as its creed the best service of the profession to the society of which it forms a part, then there will be in the end no engineering profession. Professional status rests in perpetuity, not on transient law, not on the cruder machinations of the

ancient guilds, not on exclusive control of those having a specialized and necessary knowledge; but upon the respect and fundamental support of the people who are served; who only in the long run can insist upon the maintenance of prerogatives, and confer honor, recognition, and special privileges in society upon the members of a profession.

Will engineers support such a program? Will they contribute directly or through their specialized societies to the development of this ideal, and its exemplification in Council projects aimed at rendering real some aspect of the profession's contribution to public welfare? Will they make possible great forums for the crystallization of engineering opinion on public questions involving engineering, not to attain an impossible unanimity or produce high-sounding resolutions, but so that all aspects of controversial matters may be aired in order that people may know what engineers think? Will engineers go along heartily in developing a professional consciousness, a code of action, a philosophy which implements a desire to be a truly professional group, oriented primarily toward the advancement of the public health, safety, comfort, and progress? Will they accept as the central theme the engineers' ministration to society, without fear of any class, and without prejudice toward or away from any special social interests or causes?

If they will not, then there is no truly professional spirit to build upon. We may as well resign ourselves to a gradual absorption as controlled employees, and to the disappearance of our independence. We may as well conclude that we are merely one more group of the population, trained with a special skill, maintaining our economic status by a continuing struggle against the interests of other groups, forced in this direction and that by the conflict between the great forces of a civilized community; with no higher ideals than to serve as directed, and with no greater satisfaction than the securing of an adequate income as one member in the struggle for the profits of an industrial age.

But I know the minds of too many engineers to be thus pessimistic. I recognize the distinguished careers of a generation of men who have practiced in the profession to its credit and honor. Though the task be difficult, on account of the nature of many of our relationships to society, nevertheless traditions are being formed, the consciousness of the membership is becoming aroused, and I confidently expect the profession of engineering to develop in a manner of which we can be justifiably proud.

And to those in the ranks, who may not have yet seen the light, I would preach the doctrine, without pulling any punches, without mincing any words, that the path of professional attainment lies open before them, that it is a thorny path that is easily lost sight of among the rocks and rubbish, that it can be adhered to only by sacrifice and by support of those who lead the way, that it is a long path which leads down into the valley into which the sun does not shine, but that it leads at last to the heights. To the heights of true professional attainment, where honor and individual recognition by fellows is the real reward, and where the watchword is that old, old theme, which has never lost its power, and which may yet save a sorry world, simple ministration to the people.

# An Exciting and Pleasant 40 Years

By F. B. JEWETT
FELLOW AIEE

***In accepting the 1939 John Fritz Medal, Doctor Jewett cited a "few fragments" of his history and philosophy***

ON OCCASIONS like this it is expected that the medalist say something about his past which presumably he thinks may have borne on the award. Since the matters discussed by the committee of award around the council fire are never disclosed, this is a dangerous thing and one to be invited only by stoics. If the medalist chances to hit on things they have approved, they may be pleased but must wear the mask of vacancy. They must wear it also if he esteems things they consider of little or no merit. It is an irreversible process. I am going to avoid both Scylla and Charybdis by the simple process of crawling overland and dropping a few fragments of my history and philosophy.

As I look back over my life, two things impress me: one is the time and place of my birth; the nature of my education, and the character of the men it has been my good fortune to know and work with; the other is that far from my having anything to do with it, the course of my life has been essentially the antithesis of a planned career. However vigorous I may have been at times in

Essential substance of an address delivered at the John Fritz Medal presentation ceremonies during the AIEE winter convention, New York, N. Y., January 25, 1939.

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some adventure, in honesty I must confess that I have been essentially a drifter continually taking up the things of the moment that I thought needed to be done.

I have known many men and women. In the main I have found them worthy and have truly liked them. I have found some who were "brass hats" and some who were really great. If I ever had awe for the "brass hat" or for those whose importance inheres in chance occupation of an important position, I have long since lost it. If I ever lacked respect for the truly great or for those who possess any elements of greatness, I have it now and I hope in sufficient measure to override judgment based on those more ordinary qualities we all possess so abundantly.

When I left my California home in 1898 to paddle my own canoe on the stream of life, it was to depart from a community still dominated in its outlook by the spirit of the frontier pioneer. It was an attitude toward life grounded in adventure and social insecurity where men counted for everything and their clothes and the like for but little. No one growing up in such an environment could escape being influenced by it any more than the mavericks could escape the branding iron.

Of course, it was not a canoe I embarked in but the single old-fashioned wooden Pullman which on most days 40 years ago was sufficient to handle all the first class Kansas City and Chicago traffic the Santa Fe could scrape up out of Los Angeles even with the help of a legion of ticket scalpers.

Six years later in Boston when I left active academic life for good, it was to accept a job that I had not sought and in a field I scarcely knew existed until the job was offered to me. It seemed an attractive opportunity to do an interesting piece of work. Strangely enough the wrenching of my academic heartstrings was not particularly painful. Fortunately for me it did not part them, however.

For a number of years this new life in the telephone field was little more to me than a tremendously interesting and exciting technical job. I did not know then how deeply I was to become enmeshed in the philosophy on which the Bell System is grounded nor how far my admiration of that philosophy was destined to carry me into remote fields of education, engineering, the urge to foster the development of scientific research and public service in both war and peace.

Possibly I have overestimated the wisdom of those who 50 years or more ago had great visions and created the pattern of the Bell System. Possibly I have overrated the mechanism they set up to fit that pattern and have placed a too great worth on all the physical and social results which have been the direct heritage of men's thinking and planning five decades ago. It is not so much that I marvel at the visions—we all have those—but that men should have the wisdom to see that realization of their particular vision called for a pattern and mechanism which was iconoclastic. Of course they could not see all the results of their planning and in many respects they built better than they knew.

We who have followed and who have used and improved the tools they created know that great technical achievements which have not been duplicated or approached elsewhere have resulted. We know that this is because of a unique philosophy and setup and not because of any extraordinary prescience on our part. My own work has been mainly in the technical sector where the barriers of distance have been annihilated so far as speech is concerned and where here in America as nowhere else the goal of an ideal telephone service is within sight. I am proud to have had a part in the work.

But my admiration goes much further for I have seen the influence of that wisdom exerted on men and women to develop in hundreds of thousands of them an ideal of public service in which elements of self-interest and mere money grubbing play no dominant part. It is an ideal which makes no hypocritical disclaimer of a proper profit motive as a necessity in the attainment of an ideal service. When the books are finally balanced in the distant future I am not at all sure but that more credit will be given us of the Bell System for pioneering work in the mechanism of relating applied science to the art of living than for all we may have done by way of applying science usefully.

I can speak thus confidently about tens of thousands of my associates whom I have never met because I know of the influences that have operated on me and the results thereof. They have not been the influences created by small thinking in those far-off days.

My expeditions into the fields of education; stimulation of research in the domains both of fundamental and applied science; and public service of various kinds all, in a way, have been collateral offshoots of my main interest.

I have seen great changes in scientific and technical education. From the standpoint of the quantity, quality, and variety of food available, there can be no question as to the advance since my youth. From the standpoint of the cooking and serving there has been improvement though not so striking, I think, except in a trade-school sense and hardly commensurate with the vast amount of conscientious devoted effort expended on it. Still it has improved in a practical way. It is in the sector of true scholarly education, however, that progress seems to me to have been most uncertain. Possibly it is a field in which nothing much can be done since probably the capacity for such education is a result of genes and hormones hardly likely to be changed radically by outside influences.

I cannot but wonder whether our frantic present-day efforts to advertise and dramatize the wares we are prepared to vend at our educational institutions are really incentives to increased scholarship of the kind that really makes for advance in science and engineering as elsewhere. I wonder.

In the domain of research in fundamental and applied science and in engineering, the picture of improvement and results is crystal clear. In a manner of speaking, industrial research in its modern sense has come into being in my active lifetime. It was a hard job to get the load started and wagons up the first long hill—in fact, to find enough horses to pull them over the rutty road. Now, however, with a smooth highway leading apparently downhill into the promised land, there is some danger

that the horses may get run over if the drivers are careless or the brakes fail.

Altogether it has been an exciting and withal a pleasant 40 years for me since I left the orchards and vineyards of southern California to plunge into grown-up life four days later in Chicago through the doorway of 28 degrees below zero and a 60-mile-per-hour northwest wind. I hope I have added something to the pile of worth-while things and that I may add more. Whether or not this hope is justified I do know that in many respects the world of tomorrow which my boys are entering is a much better world than mine was; but there is more to challenge and excite. Even in the field of science and engineering, while we are leaving them a mass of troubles, we are likewise leaving them an improved kit of tools with which to cope with those troubles.

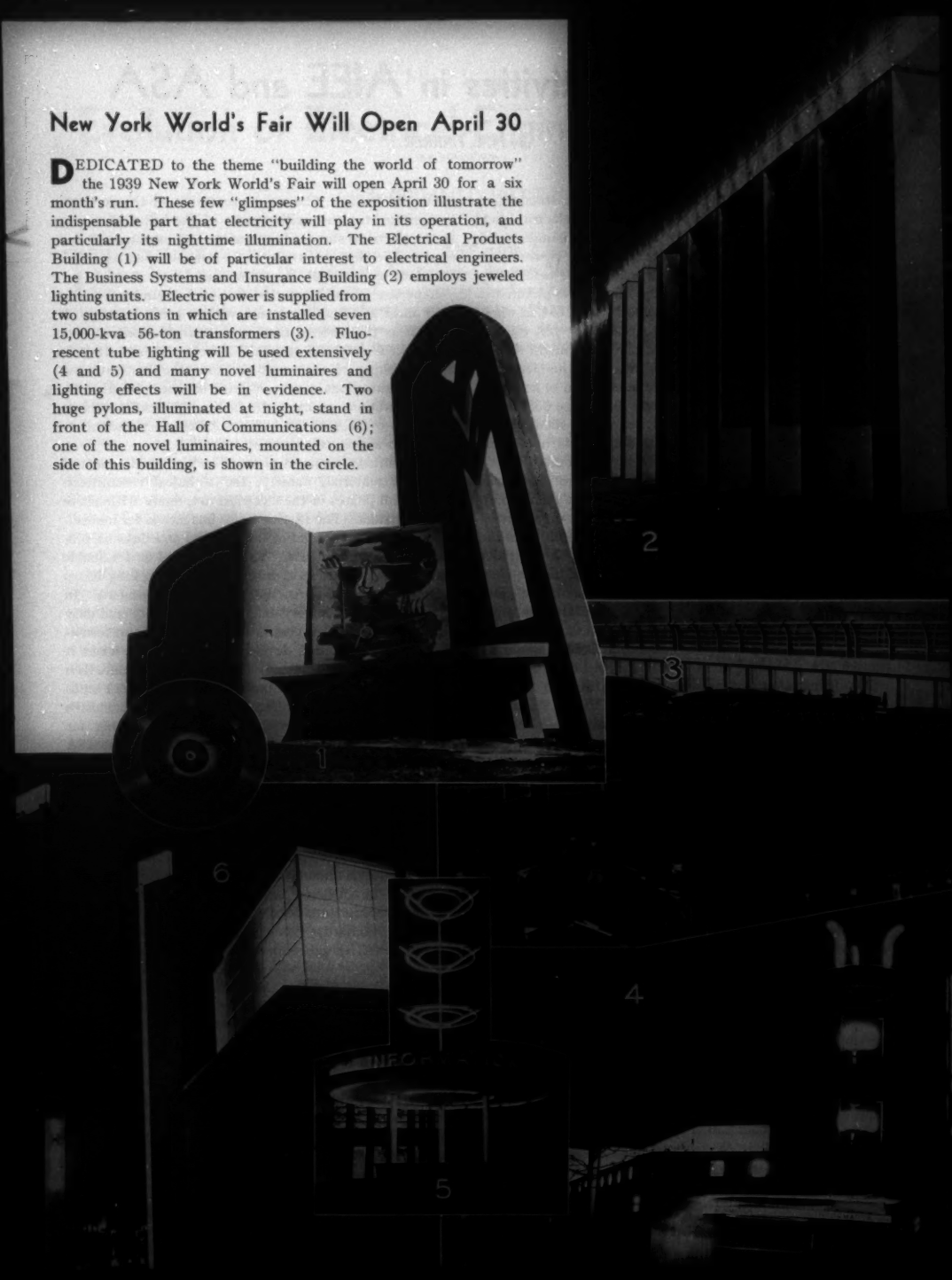
In conclusion I can only express my appreciation for the honor done me and through me the associates in many fields for whom I stand as a symbol. I gladly accept the 1939 John Fritz Medal for myself and as a trustee.

## Members Invited to Visit AIEE Headquarters

MEMBERS coming to New York City to attend the World's Fair, or for other purposes, are cordially invited to call at Institute headquarters, 33 West 39th Street, and to take advantage of the opportunities there offered for correspondence, conferences, receipt of mail, and assistance in connection with inspection trips and other matters. Headquarters are in the Engineering Societies Building, the entrance to which, shown in the center, leads directly to the lobby pictured at the left above. Below, right, is the reception lobby of AIEE headquarters on the 10th floor. In the center below is a corner of the members' room and at the lower left the gallery of past AIEE presidents. Members may wish to visit also the Engineering Societies Library, right above, on the 13th floor.

# New York World's Fair Will Open April 30

DEDICATED to the theme "building the world of tomorrow" the 1939 New York World's Fair will open April 30 for a six month's run. These few "glimpses" of the exposition illustrate the indispensable part that electricity will play in its operation, and particularly its nighttime illumination. The Electrical Products Building (1) will be of particular interest to electrical engineers. The Business Systems and Insurance Building (2) employs jeweled lighting units. Electric power is supplied from two substations in which are installed seven 15,000-kva 56-ton transformers (3). Fluorescent tube lighting will be used extensively (4 and 5) and many novel luminaires and lighting effects will be in evidence. Two huge pylons, illuminated at night, stand in front of the Hall of Communications (6); one of the novel luminaires, mounted on the side of this building, is shown in the circle.



# Standards Activities in AIEE and ASA

By H. E. FARRER
ASSOCIATE AIEE

APPARENTLY the complexities of the standardization machinery in operation in the electrical field today is continually leading to misunderstandings, particularly among the members of the Institute uninitiated in standards rites. These erroneous beliefs vary all the way from one in which the Institute is pictured as having resigned all interest in standards work, to that where the AIEE is preparing again to take over full control. Both statements are far from the truth and might lead to unfortunate developments. An attempt therefore was made over a year ago through the publication of an article in ELECTRICAL ENGINEERING (June 1937, page 653) to get a clear picture of the situation before the membership. With the same goal in view, this article is now being presented but from a slightly different viewpoint.

Since the days of 1918 when the American Standards Association was established on the basis of a plan formulated by the AIEE, the scope of work of that organization has grown so tremendously that even the simplest outline of all the various undertakings would require a pamphlet of considerable size. Under present procedure the electrical standards committee of ASA, representative practically of the entire electrical field, is essentially the court for American approval of electrical standards. These standards may have been developed under the sectional-committee procedure of ASA, or they may have been entirely formulated and presented for approval to ASA by standards-making organizations similar to the American Society for Testing Materials, the National Electrical Manufacturers Association, or the AIEE. Final action granting approval as American Standard lies of course with the Standards Council which, however, naturally looks to the ASA electrical standards committee for recommendations on electrical matters.

In developing a standard by means of the sectional-committee procedure of ASA, the first step consists of a general survey of the field involved with a view to the selection of the proper bodies to be represented on a "sectional committee" and the selection of a sponsor for the undertaking. The sponsor, holding largely an administrative supervision, may be either one of the interested organizations in the field to be covered, or may be the electrical standards committee itself. The work of standards development from that point on is simply the normal procedure followed by all standards-making bodies. Final approval must be obtained by means of ballot. The recommendation of the sectional committee, together with results of the ballot then goes to the electrical standards committee for examination and approval, leading eventually to the issuance of an American Standard or American Recommended Practice.

Experience has shown that sectional committees can do their most effective work and with a great economy of time, if as the basis of their work a draft standard or a report on a proposed standard is before them. It is in the furnishing of such material that the Institute and other organizations can be of great service. In all cases, where conditions warrant, the Institute has submitted its standards to ASA as the basis of American standards or such other action as is deemed desirable.

The Institute has an ideal setup for the development of standards material, namely, the technical committees, covering all phases of the electrical art, many with active subcommittees. The Institute also has means for immediate and wide circulation of information and data on proposed new developments. This is essential and valuable in keeping standards up to date and in avoiding long delays in final approval of revisions and new developments. In other words, it is the very definite responsibility and duty of the AIEE technical committees to prepare and formulate standards material, developing it to a point where it is satisfactory to the industry. The current procedure then is for an AIEE technical committee to pass this work on to the AIEE standards committee. The standards committee then approves the material, if satisfactory, either for publication in report form, or for transmittal to the ASA for consideration and approval as American Standards. There may be exceptions to this procedure, in which event action should be based on the conditions applying to the particular situation.

In the past the Institute considered as outside its field dimensional standards and other similar questions involving more or less commercial matters. Under ASA all these things may be gathered together and with related test codes and recommendations on operation form complete American Standards—something that never was obtained under AIEE procedure only.

It seems fair to say that the present setup while apparently unduly complicated, actually lends itself admirably to the solution of the varied problems continually developing in the electrical field. Solutions can now be found to situations that at one time seemed hopeless. There is still work for all and plenty of it.

**Standards form the basis for a necessary common language for the discussion of electrical machinery and other apparatus, and serve as one of the principal means for getting research results into actual use in industry. Formulation of electrical standards is an important function of the AIEE, which has an ideal setup for their development. Approval as "American Standards" is a function of the American Standards Association, a joint agency of which the AIEE is a "member-body."**

H. E. FARRER is a member of the AIEE headquarters staff and has been secretary of the AIEE standards committee since 1923.

## Some High Lights in the

# Evolution of Electrical-Engineering Education

By DUGALD C. JACKSON
FELLOW AIEE

**The award of the AIEE 1938 Edison Medal marked the first time that the term "engineering education" appeared in the formal citation of the recipient's achievements. Hence it appears quite logical that Doctor Jackson, who received the award, should discuss that subject in his acceptance address.**

THE CITATION that the Edison Medal committee has so graciously joined with my name couples engineering education with engineering practice. That never before has been done explicitly in an Edison Medal citation. Indeed the phrase "engineering education" never before has been used in such a citation. The use here seems to me significant of the present relation in the field of electrical engineering, where education and practice are now recognized as complementary parts of one whole; and it turns me to the theme of engineering education, to the exclusion (at this time) of directly discussing the science and art of electric-power practice which is the conjoined part of the citation.

In the beginning of the last decade of the 19th century, electrical engineering was young and its devotees likewise mostly were young. As it usually goes in a young art, there was endless opportunity for exercise of the quality of quick creativeness, and therefore those of us who were in it were having all the pleasures and most of the perils of joyous adventure, with the reassuring result that the art was moving forward and expanding rapidly although the movement seemed slow to our ambitious minds. The responsibilities were large, but most of us were young and resilient and bore them satisfactorily as we pushed our way through the thicket of the partly-known or the jungle of the unknown.

While I was in the midst of this absorbing life at the opening of the last decade of the 19th century, there came to me from T. C. Chamberlin, then president of the University of Wisconsin, an invitation to visit him at Madison, the seat of the University—which I did. He offered me the faculty post at the head of a department of electrical engineering just authorized for the university. Madison was beautiful. It had expansive lawns shaded by many oak trees. The lake alone was adequate to fill the eye with beauty. I fell to the charms. The apple went to gain the fair Helen. But in spite of the precedent tribulations of Paris and the downfall of Troy, I never regretted the choice.

Chamberlin was a geologist of great intellectual power. Later as head of the department of geology at the University of Chicago he proved himself one of the nation's great scholars and of international fame. Before his time there had been some mild engineering instruction at the University of Wisconsin, but he gathered together a faculty group to cover the then principal branches of engineering. All of us, I think, had been successful as employees in engineering affairs relating to our respective branches, and some had been additionally proved in experience as teachers. We all were young. Indeed, some of us were scarcely dry behind the ears. I was 26 and head of a newly established department with no precedents to follow therein. It was early in electrical engineering and still earlier in organized electrical-engineering education. It was only six years since bachelor's degrees were conferred for the first time at Massachusetts Institute of Technology and Cornell University, which were the pioneer institutions in establishing formal curricula in electrical engineering. The AIEE itself was only seven years old.

By this time (1891) there were formal electrical-engineering curricula in a considerable number of institutions, but substantially all had been established under the aegis of departments of physics and most of them still were directed by such departments. We were breaking sod in electrical-engineering education because at the University of Wisconsin the department was established at once as part of an engineering school and co-ordinate with other engineering departments. That is the best of practice now, but it was irregular then. We owe a debt to the physicists for starting into electrical-engineering education when they did, but later experience has proved the soundness in education of dealing with it as a coequal branch of engineering.

I refer to these things because they aid in showing the development of a philosophy of education in electrical engineering which seems to me to have had a considerable influence throughout the land. Chamberlin told us that in the great plains area of the United States college teachers of engineering were rather jeered at on the ground of being theoretical and consequently unpractical, and that we must maintain the proof of our competency in engineering. This meant authorization for some practice as consulting engineers, which suited me, because (while I had previously carried responsibilities in engineering work) I could not be content to plan a way in engineering

Essential substance of an address delivered at the Edison Medal presentation ceremonies during the AIEE winter convention, New York, N.Y., January 25, 1939.

DUGALD C. JACKSON is professor emeritus of electrical engineering, Massachusetts Institute of Technology, Cambridge, Mass. A biographical sketch of Doctor Jackson appeared in the January issue (page 80); an article outlining his qualifications for the Edison Medal appeared in the February issue (pages 64–6).

education without maintaining a continuing intimacy with the advancing front of engineering practice. That was more important in those early days than it is now, but the idea still possesses real vitality when properly applied.

Chamberlin was a scientist and he had an intuitive recognition of engineering as a profession relating to applications of the sciences and as far different from even the highest order of artisanship. He expected us to prove ourselves scientists. We also had to prove a capacity for influencing students, which meant (for those of us who had not already done so) breaking into the art of pedagogy in a limited but important sense. The first of these was relatively easy for those of us who had laboratories or field duties under our control. We were young and full of queries as to why things occurred and about the interrelations of physical phenomena; and we used our students to work out our problems (for which we tried to make them competent) or to strip the ground for us so that we could dig at main kernels more directly. Incidentally, this was good pedagogy when used so as to put our students individually on their mettle, but I do not think we were aware of that. We were enthusiastically satisfying our own curiosity and our students' curiosity about physical relationships. We did get a reputation as a group of young engineers who were also competent young scientists and who attracted to them ambitious and resourceful students. This resulted in our growing group being frequently raided for the benefit of some other universities, to our grief at loss of colleagues, but also to our satisfaction at such recognition of our serviceableness.

## Recognition for Engineering Faculty

It was not so easy to gain acceptance in pedagogical lines from conservative members of faculty who cultivated the classics, philosophy, literature, and other humanistic fields. However, various incidents arose that resulted ultimately in our acceptance in full as adequate members of the university faculty, and our relations were very happy. It was about this time that a near neighbor of mine, an authority in classical languages and literature, whom I highly regarded, said that he found me "very well read for an engineer." I had difficulty in convincing him that I could not accept that as the personal compliment for which he intended it because, if I did, it became such a sad reflection on my profession which we were trying to get people to realize is as much a field of learning as (for example) medicine or law.

Our engineering faculty group at the University of Wisconsin promptly went to work in defining our objectives and the programs for advancing toward those objectives. We explicitly formulated the understanding for the four-year undergraduate curricula that the objective was not to make engineers but was to make young men with "a great capacity for becoming engineers," since greatness in engineering usually comes with the years of wide experience. This, in my opinion remains a good aim for the undergraduate curricula of the engineering schools, since too close attention to engineering practice prevents applying sufficient attention in the college to the essential sciences and political economy of which the applications make the structure of engineering. But I completely disagree with those who now urge that the tenet should equally apply to all graduate work in the engineering schools.

Our laboratories became more versatile and our library more extended as we struggled at Wisconsin to develop in our students individual initiative, self-reliance, and resourcefulness by processes of self-education learned by them while absorbing the facts and interrelationships of science and political economy. We were quite unconventional, but the processes worked. The engineering school of the University of Wisconsin grew in a dozen years into quite a reputation for creditable achievements in engineering education. In directing this project of higher education leading into engineering, some of us came to recognize that "There is one glory of the sun and another glory of the moon and another glory of the stars." Also that among teachers and students there could be indeed very few suns or moons, but of stars there might be many; and of them we learned to remember that they may be infinitely varied in their brilliances, their tastes, and their prospective effectivenesses. "One star differeth from another star in glory" also said the Apostle, referring to tangible appearances. We thought of these words, but applied them to the imponderable human characteristics of the individuals. It also led us to the maxim that each member of the growing electrical-engineering staff in the University must be a master in a creative way of some particular aspect of electrical engineering, who also possessed a wide general knowledge and interest in all human activities and particularly in the activities of ambitious young men.

When things were well under way, we started some graduate work in electrical engineering, and perhaps a little in other engineering branches, still with the individuality of the students in mind. Then, after a time we took to reanalyzing the history and developed scope of electrical-engineering education and practice in this country and Europe, with the purpose of criticizing our own processes in the educational field and learning whether our emphases were wisely set. This led us more and more to treasure and encourage student initiative and independence in laboratory work.

## Applying Wisconsin Methods at MIT

After 15½ years of this fascinating development work, it was my fortune to go to the Massachusetts Institute of Technology in the post of professor in charge of the department of electrical engineering, there to set up the processes established by the Wisconsin experience. At MIT the course was the oldest in the history of electrical engineering, having been established in 1882, and it had a very distinguished background in its more than 600 alumni from 22 classes. Many of the alumni already held important places in the electrical field. The executive committee which controlled the institute for the corporation was composed of devoted and distinguished men, several of them being important men in the electrical

field. It was a stimulating situation and the department, in staff and students, about equalled in numbers those to which the department at the University of Wisconsin had grown; but the equipment was not the equal of Wisconsin's for fertile teaching, and the space was cramped in some of its aspects.

The MIT curriculum had become, with the course of time, overconventional, and the department staff was endeavoring to do too much of itself instead of relying sufficiently on fellow departments in collateral fields like mathematics, physics, mechanics, thermodynamics, and so on; this tended to prevent opportunity for the individual members to become creative masters in their own chosen branches. We promptly revised the curriculum with the object of enlarging student independence and individual vision. We substituted the principle of the continuity (unity) of learning in place of the bit-by-bit dealing with electrical engineering as a series of concrete, inadequately dovetailed parts which was then fashionable and which has not yet been everywhere abandoned; and we cultivated an intimate co-operation with collateral departments.

## Valuable Relations With Industry

The great industrial activity of our neighborhood enabled us to cultivate closer relations with the industries than had been practicable in the Middle West, and we gained great advantage from the generous advice and aid of important men in the industrial field. This was important because electrical engineering is largely industrial, if we think of industry as inclusive of the public utilities as well as of manufacturing and its concomitants. I think it also was a stimulus to the growth of that sense of responsibility toward supporting sound engineering education which now is found in various industrial circles. It also ultimately led to the joint establishment of the clearly defined co-operative curricula in electrical engineering (in which MIT and each industry concerned bear mutual responsibility for the educational procedures) which now absorb the attention of over one third of the electrical-engineering students at MIT. In our teachings, we markedly emphasized the research aspects of the higher levels of engineering activities.

Here, as we grew and were granted more space and funds, we came to understand that a suitably directed large department with many students of varied tastes and fine abilities may prove to be more invigorating to the individual students than a smaller department may be. But there are certain restrictions which must be recognized. The department must have allocated for its use both space and funds which, on the basis of per capita of students, are fully equal to those of the small department; and it must have a staff membership which is fully as large per capita of students as characterizes the small department. That staff must be a group of scholarly and creative masters, each leader being a notable specialist in his own subdivision of electrical engineering and characterized by enthusiasm for science and equal enthusiasm for encouraging the independence of students while passing on to them his own best qualities. It is this variety of contacts with notable men available in a well-directed large electrical-engineering department that produces the notable stimulation.

The point which I emphasize is that in engineering education no curse rests on bigness because of bigness any more than either a curse or a blessing rests on smallness because of smallness. In either case, realizing the fullest service for students and for the engineering profession depends on the educational statesmanship coupled with the scientific creativeness of the department. If that combination is adequate, a well-staffed and fully supported large department may be more stimulating to students of high grade than a small department. This applies equally to graduate students and undergraduate students in their individual accomplishments.

## Developing Student Responsibility

In such a department the highest success depends on the undergraduate classes being divided into small sections, selected according to the tastes and mental speeds of the students, honors groups being organized with prime responsibility laid on the members for their own education aided by seminars and sympathetic counselors selected from the staff, searching examinations being offered which cover as a unit the entire field studied, large freedom for self-chosen investigation being provided in the laboratories, and (as they advance) the students being encouraged to participate as self-reliant individuals in staff research. By these processes stimulus toward full self-development is equally offered for the infrequent suns and moons and the more frequent stars within a range of brilliancy, as they occur among competent students of engineering. For success in the adventure, each leading man on the staff must have mental qualities that give him strength in science, in scientific research, and in the applications of science, accompanied with strength in pedagogical qualities that lead him to sympathetic interest in the intellectual progress of students; and a spirit of co-operation must be maintained among the staff members, which is difficult in a group of individualistically minded stars.

Such men are difficult to find for the staff. They are far scarcer than men with fine research capabilities in science or men with fine pedagogical capabilities, who do not possess the twin capacity. It has been my fortune to find among my colleagues many such unusual men to whom I am glad to express deep indebtment. I wish I could tell you about them and the manner of their achievements, but that would require a substantial history of the electrical-engineering department of MIT and particularly of its last 30 years, which would be a long lecture of itself. Space protected from the weather, equipment for extemporizing experiments in research, and a properly supported staff of men with the qualities described, under sympathetic leadership and freedom to carry on, will result in a great engineering school anywhere; but not infrequently the proper spirit is not there or the necessary conditions are not provided and the engineering school

is but an aspiring, or (worse yet) an unaspiring, nebula instead of a glowing star in the educational firmament.

A fine, creative department is costly to maintain. A good engineering school spends more money on its productive educational work than it receives in tuition fees from its students, and any university chief executive who believes that a great engineering school can be run at less cost per capita of students than a great medical school, aside from hospital costs, is supporting an unfounded supposition. One fault attaching to our engineering education is that a few of the universities that support medical and various other branches of education on a high level of scholarly fitness are willing to see their engineering schools lie in the neutral space of semiprofessional, semiartisan activities, with minor emphasis given to scholarly and creative qualities. Naturally, such institutions fail to secure (or keep) scholarly men for leaders in their engineering work.

One more word: H. C. Bunner one time remarked, in a burst of characteristic humor, that Shakespeare "lived by writing things to quote." No one will gainsay either the greatness or quotableness of the great poet's writings, or deny that they are much quoted. So I will quote: "A jest's prosperity lies in the ear of him that hears it." That is a saying of truth and is worth remembering. We of this age may paraphrase that and say that a consulting engineer's repute lies in the minds of his clients, and a teacher's contributions lie in the achievements of his students. In these respects the engineer or teacher is but a catalyst and is not a direct factor in the reactions that occur except to stimulate them in the origin, to encourage them as they grow, and to give them range. It is having this in mind that gives me so deep an appreciation of the gift of the 1938 Edison Medal as a thoughtful token that something permanently serviceable has been accomplished.

## Some Comments on

# Graduate Training for Engineers

***Representative industrialists and educators see value in postgraduate training in some situations, but such training cannot be evaluated in advance in terms of individual progress, nor is it in most industrial fields a substitute for actual experience***

QUESTIONING the value and adequacy of postgraduate engineering courses as commonly conducted, L. W. W. Morrow in an article in ELECTRICAL ENGINEERING for March 1939, pages 118–22, called for a program of investigation of postgraduate training. Solicited comments of some representative industrialists and educators are presented here.

**M. W. Smith** MEMBER AIEE

Mr. Morrow has developed a number of questions and made many constructive suggestions regarding the objectives and achievements of graduate training for engineers which deserve careful consideration by those responsible for the planning and execution of this kind of educational work as well as those who are contemplating taking graduate work.

The inference that industry offers no special inducement to men with graduate training is no doubt justified to a large extent, although the value of such men for special advanced assignments like research work is generally recognized and appreciated by industrial management. The justification of a more general use of graduate engineers in industry will depend upon the extent to which their training can be planned and conducted to meet general industrial conditions and requirements. Industry will probably be slow to recognize graduate engineers as a special class for universal application, but as individuals having such training demonstrate its advantages through unusual or extraordinary accomplishments, the value of this kind of training will be appreciated just as other special training, fellowships, and so forth now supported by industry are recognized and successfully applied.

Graduate training is usually conducted along the lines of "more of the same" with the result that about all the student acquires is a greater accumulation of knowledge and information on the particular phase of the subject in which he specialized. This procedure and training, of course, makes the man a more valuable specialist and one who will probably advance more rapidly in his particular line of work.

Such a plan probably does not represent the fullest possibilities of graduate training nor fulfill all the needs of industry. The normal undergraduate training qualifies

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the student with average or exceptional ability to advance satisfactorily through the normal channels of specialized activity in an industrial organization, and it should be recognized that the normal forces of individual competition and demands for maximum efficiency of operation and output naturally tend to confine a man to a relatively limited field of activity in which he is likely to remain if his previous training is entirely of a specialized nature and if he does not broaden his education and qualifications through outside work and training. One of the problems with which industrial management is continually confronted is to find technically trained men with the qualification of leadership required successfully to direct the efforts and activities of others. The qualifications for leadership of course involve human characteristics, personality, and many other factors, but is it not possible that to some extent the deficiency may be influenced by limited views and perspectives resulting from education in restricted and specialized fields even though the training may be basic and fundamental? If this be true, then it would seem that there exists the possibility of enlarging or expanding graduate student training so that in addition to the usual specialized training which is required for the purposes and objectives of most courses, there should be an opportunity to plan and conduct the graduate work so as to broaden its scope in a way that will develop a better conception of the importance of and relation between the various branches of engineering and science. An understanding of more branches of science and an appreciation of their relationship will better prepare the student for observing and absorbing information relative to the varied over-all engineering operations of a particular industry and thus give those who are not content to remain in specialized activities a better opportunity to prepare for and undertake broader management responsibilities.

Because of its vital interest in the training of students, industry would welcome the opportunity to work with college faculties in the consideration and development of plans to broaden and improve the training for graduate engineers along the lines suggested by Mr. Morrow. This is a problem of mutual interest, and a closer relationship providing for a free exchange of ideas and experiences is certain to produce better results.

**A. R. Stevenson, Jr.** FELLOW AIEE

Mr. Morrow's excellent article is of great value in raising many questions which stimulate thought on the subject of "Graduate Training for Engineers." In a short space there is hardly time to discuss more than two phases of the subject.

1. A few colleges are now turning out doctors of philosophy in engineering that are valuable in industry as technical engineers. These colleges have at least one outstanding professor who, by his excellence in his profession and by his personality and character, attracts the right kind of candidates and gives them training, inspiration, and an opportunity to develop.

According to well-established tradition, James A. Garfield is quoted as saying at an alumni dinner in New York City in 1872:

> My definition of a university is Mark Hopkins at one end of a log and a student at the other.

This is the real crux of the situation. There is too much tendency today throughout both education and industry to put faith in false gods such as organization and facilities. These are important, but they are absolutely secondary and minor compared to the supreme importance of individual inspiration and leadership. Many colleges have put too much money in laboratories, in organization, in curricula, and in hosts of instructors, and then cannot afford to hire the one important element which would motivate the whole as the spirit motivates the body, a professor who is a great man.

The value of the degree of doctor of philosophy in the fields of physics and chemistry has been recognized more widely by industry than the same degree in engineering. The reason perhaps is that these fundamental sciences can more easily be practiced in a college laboratory. The science professors do researches which even though theoretical may be called practical in the best sense of the word because they lead to useful results. The graduate students associating with these professors get the stimulus of helping in real creative enterprises.

The necessity of such practical enterprises as a part of education is indicated in the following quotation from John Dewey's book "How We Think":

> The assumption that information which has been accumulated apart from *use* in the recognition and solution of a problem may later on be freely employed at will by thought is quite false. The skill at the ready command of intelligence is the skill acquired with the aid of intelligence; the only information which, otherwise than by accident, can be put to logical use is that *acquired in the course of thinking*. Because their knowledge has been achieved in connection with the needs of specific situations, men of little book-learning are often able to put to effective use every ounce of knowledge they possess; while men of vast erudition are often swamped by the mere bulk of their learning, because memory, rather than thinking, has been operative in obtaining it.

The doctors of medicine, law, chemistry, and physics get their stimulus largely from men who are practicing their professions.

Engineering has a tendency to deal with projects of such magnitude that it is hard to handle them in a laboratory. The teacher of engineering, therefore, is often not a practicing engineer who can stimulate his pupils by sharing with them real creative enterprises. Graduate work would be greatly benefited if the professors handling it could all be engaged part time in creative work.

2. We have all felt the disappointment of going on a vacation in search of happiness only to find the experience below expectation. Those who search primarily for security are the least likely to get it while the audacious adventurer is resourceful enough to gain security by his own wits. Many, indeed, are the examples of the philosophy that most worth-while things in life are obtained

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best as *by-products* of striving for some other more primary objective. It is true in engineering education. If the student's *main objective* is to learn, he can learn most and quickest by reading the work of others; the better it is explained, the fewer thoughts he need originate and the faster is his progress. That knowledge so gained is of little value to him later is recognized, but, if his primary objective is *to obtain a useful result for someone*, he may have to think enough to fix firmly the knowledge and the fundamentals for future use. A professor who is a current leader in engineering has such problems; he can by his own pre-eminent ability lead and challenge the brilliant student and finally, if he is a true leader, he can inculcate in the student a sense of moral and social responsibility toward mankind, an essential for those who are to shape our technical advance.

In conclusion: Correct graduate education is not primarily derived from well-equipped laboratories or from elaborately prepared curricula, but is a by-product of producing useful results in association with an inspiring leader of outstanding ability on some worth-while pioneering adventure.

## I. Melville Stein MEMBER AIEE

Mr. Morrow appears to have taken a fair and square look at both sides of the question, and seems to conclude that engineering colleges should provide graduate training for engineers, provided the program is undertaken in the proper way and only after careful study and planning.

For most of the requirements of the Leeds and Northrup Company, preference is given young men who have spent four years in college and who are then put through the company's own graduate course, requiring approximately one year. However, for research work there is a need for men who have done graduate work in college although the graduate work need not necessarily be in engineering.

I agree with Mr. Morrow that it is difficult, if not impossible, to prove a case for or against graduate study in engineering. That being so, it would seem to me that an experimental approach would be the proper procedure. In other words, if graduate engineering courses could be established in a limited number of engineering colleges and a record were kept of the later achievements of the men taking these courses, a factual basis might be established for determining whether or not such courses are worth while.

As Mr. Morrow has indicated, most major technological advances are now being made by groups of workers rather than by individuals, and under such circumstances, it is a real question whether the best results would be obtained by physicists and engineers co-operating or by a group of superengineers working without the physicists. I am inclined to believe that the former is a better arrangement than the latter, but am willing to admit that the latter group might win out. In other words, it may be difficult to obtain in a single individual, even with extended training, the proper combination of the free imagination of the theorist and the more practical point of view of the engineer.

One thing that appears to be lacking in Mr. Morrow's presentation is a consideration of the response of the students themselves. He states that at least four years should be devoted to graduate study. May there not be a real difficulty in getting the type of man who would make a really good engineer, rather than a pure scientist, to spend eight or more years in training before taking up practical work? Perhaps the answer to this is that what is sought is not really a group of "superengineers," but rather a group of "supertechnologists" or possibly no existing terminology is adequate to label the ideal product of such graduate courses. In other words, a new name may be needed.

## O. W. Eshbach FELLOW AIEE

Agreement with the analysis of the situation and idealism in objectives of graduate study for engineers as discussed by Mr. Morrow, does not justify an acquiescent amen. It implies a challenge to meet a situation which is by no means clearly understood. The paradox in it is that freedom of development of educational methods and facilities has been both the strength and weakness of current practice. One questions whether the opportunities to experiment have been fully grasped or whether unrecognized forces have limited choice and tended toward the development of a pattern that is characterized by expediency rather than ideal objectives. Certainly to judge whether graduate study is justified educationally on the basis of the character of industrial needs is adopting a poor criteria. It implies the act of following rather than leading.

One vital suggestion in the paper would seem a reasonable expectancy in so far as administrative action is needed. It is a decided effort toward better integration of what is now being done but even this implies objectives which are not easy to visualize. There is little doubt that in so far as undergraduate instruction is concerned there is need for a well-balanced and integrated program that permits greater flexibility in later choice of opportunity and at the same time would help to break down the popular conception that one must graduate in engineering with a special designation of proficiency in a traditional branch of engineering which is increasingly less prominent in creative work in life. If such a change could be effected gradually and soundly, the sequel to it would be a possibility of organizing graduate study along the more ideal pattern which Mr. Morrow suggests.

It would be unfair to imply that "learning more and more about less and less" characterizes present graduate study, but the danger is present and leads to personal restrictions likely to be interpreted to the detriment of much needed study in mature years. So long as facilities and conveniences for study while working are undeveloped

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in fields of occupational usefulness, formal study of the type we now have is not far from the most practical, as distinguished from most ideal procedure.

## Robert E. Doherty MEMBER AIEE

Mr. Morrow's discussion of graduate work in engineering is the best I have seen. Its presentation of industry's narrow outlook upon the need for men with graduate training, of the discursive and shallow nature of much that is offered or given by colleges as graduate work, and of the inadequacy of faculty personnel fully prepared to lead study at high scientific level is, I think, fair; and I therefore agree that if we accepted present experience and practice as the sole bases for judging the case, we should have few reasons for planning graduate training.

But I also agree that we should look elsewhere for the guiding light. If colleges had been guided in the early stages of engineering education by the prevailing opinion of industry as to the need of college training, they would probably have concluded that work for the bachelor's degree was unnecessary or futile, and that even if some study beyond high school did seem worth while, it should be thoroughly "practical." One does not have to go back to beginnings to find this point of view; it still lingers unbelievably. The prevailing opinion of industry is not a competent guide as to whether high-grade graduate work in engineering is desirable, because very few industries know what it is to have full-fledged applied scientists around the place. I do not mean doctors of philosophy in chemistry or in physics or in any other single field of physical science whose training has hardly touched *applied* science. There are many of these in industrial and educational research laboratories, where they belong, and some of them are doing fine *research* jobs in uncovering basic scientific knowledge. Nor do I mean the usual engineering graduate, who certainly is, in a degree, an applied scientist; nor yet the masters of science in engineering, most of whom are, in this same degree, such scientists. I mean, as I understand Mr. Morrow means, men who really *understand* the basic principles and facts of those aspects of physical science that underlie a broad field of engineering, and who have cultivated intellects—disciplined in those *essential* attitudes and techniques that will make it possible to deal effectively with knotty problems of applied science beyond the boundaries of precedent.

For light we should look not only inwardly, as Mr. Morrow suggests, but as well to a few industries where there are representatives of the kind of applied scientists we have in mind. A few industries have set up educational programs to train such scientists because they could not get them from colleges. To study the methods and experience of these would add greatly to, and I am sure would largely confirm, the idealistic concept of graduate study Mr. Morrow has portrayed. Moreover, if I may offer another illustration, not altogether without prejudice, I would suggest that the program for the doctorate in electrical engineering at Yale University be examined. Whether it will accomplish the purpose for which it was designed is yet to be seen, but it was at least framed with definite end-objectives in view at each stage, and those objectives are almost precisely those Mr. Morrow has specified.

There are, however, two or three points in his plan on which I would comment. One is the extent of factual knowledge required at the start. This should be limited to the utmost minimum required to implement theory, or, as he says, "focus the abstract scientific knowledge." This minimum is still of very large scope, and to settle upon the *minimum essentials* in a rounded-out, integrated program is one of the most difficult educational problems I know. But it is solvable. It must be remembered in any study of this matter that the best place to acquire the specific facts of a specific job or problem is *on the job*. This lesson, by the way, is yet to be learned even in undergraduate work.

Another point is that "the man needed by technological industry must be able to state his variables at the start of a problem. . ." If the problems are of the type I believe the author has in mind, I should regard this as optimistic. I've never seen anyone who could do it and *know* that he had stated them all at the start. But I agree that the more he can identify at the start, the better.

And finally, I think I probably see greater reason than he does for insisting on reasonable literacy regarding the interdependence of social and technological developments. I contend that unless we are content to give merely lip service to the theory of democracy, we should set down as a specification that professional men, especially those in science and engineering, should not be socially illiterate.

## R. W. Sorensen FELLOW AIEE

Mr. Morrow's timely and comprehensive article presents almost every angle of the subject as expressed by many persons of varied experience and attitude toward education who were interviewed by him. Assuming that his title, "Graduate Training for Engineers," means a program of study and research carried on in residence at a technical college by men who have completed a regular four-year college course, I would like to supplement his paper by citing some observations and results within the scope of my own experience.

My first premise is that the art and science of engineering now have reached a stage where graduate schools for engineers are absolutely essential for the continuance of the engineering profession on the high plane it now has, and on the plane which we all desire and which is the goal of the four Founder Societies, the Engineers Council for Professional Development, the Society for the Promotion of Engineering Education, and the National Council of State Boards of Engineering Examiners.

If this point is well taken, the next question is, "Who

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should take graduate engineering courses and what subjects should be included in graduate curricula?" I believe that one-fourth or perhaps one-third the young men now graduating from four-year engineering courses should take at least one year of graduate work. The courses for those who take only one year of graduate work should not differ greatly as to type from the undergraduate upper-division courses of our better engineering colleges; that is, the one-year graduate curricula should include courses which enable the student to get well acquainted with special subjects such as long transmission lines, advanced work in the characteristics of electrical machinery, laboratory work of research nature, and to obtain increased facility in the use of differential equations and other advanced mathematics and physics as applied to engineering problems. If one-fourth to one-third of the engineering graduates from four-year courses continue for a year or more of graduate work, the undergraduate courses may also be improved by deferring some of the special technical subjects now given in the senior year to the graduate school and using the time thus made available in the undergraduate years for the humanities to an amount equal perhaps to 25 per cent of the total time available for study in the four undergraduate years. This may well be done to good advantage for all men taking engineering courses, because the undergraduate courses will still contain sufficient technical content to enable engineering graduates to carry on all the technical work involved in many phases of our profession and at the same time will give the four-year-course men a better general knowledge, thus better fitting them for many semitechnical and management positions than can be done by courses in which practically all the time of the undergraduate years is devoted to technical subjects.

Furthermore, the natural expectation is that the men who will take graduate courses are the men who because of their own desires and superior aptitude in the strictly technical phase of engineering have been encouraged by their teachers to take graduate work. My experience has shown that students mature very much more during their fifth year of work than during any of the four undergraduate years and that they obtain a well rounded grasp of the whole scope of what constitutes the work of an engineer, far in excess—as measured by time spent—of an added college year.

Graduate engineering colleges should also provide for a very select group of men of special ability three or four years of graduate work leading to the doctorate degree. The number of students who can qualify for and profit by this larger amount of graduate work probably is not more than five per cent of the number graduating from the four-year undergraduate engineering courses. Graduate curricula for such men should not be made up, to any great extent, of engineering courses designed to make men more proficient in the same type of technical work as that included in undergraduate courses, but rather the course work of graduate curricula for doctorate-degree engineers should be made up very largely of advanced courses in modern physics and mathematics, which with a bit of economics and chemistry coupled with "tie in" engineering courses and an engineering research problem, constitute a well rounded whole. In order to have such an arrangement function effectively, co-operation is absolutely essential between the science and mathematics faculties and the engineering faculties, so close that all departmental division lines are practically eliminated. Of course, it goes without saying that such a condition can exist only when the colleges concerned have outstanding science and mathematics departments sufficiently staffed by men who know what the engineer is trying to do and who are sympathetic with his program to care for the engineers who wish to take that work.

For 15 years I have had a part in assisting a considerable number of young electrical engineers through graduate engineering courses of this type. During that entire time —which also includes our recent depression years—the demand for men who have completed the work for their doctorate degrees has greatly exceeded the supply. Electrical engineers with doctorate degrees thus educated have been employed at premium starting salaries by colleges and by industry. In fact, the demand for such men and for the men who have completed one year of graduate work by industry has been so much greater than the California Institute of Technology graduates available that Mr. Morrow's statement—"some manufacturing executives say it is foolish for engineering colleges to give graduate work"—gives me no concern.

There is much more I would like to say regarding experiences in conducting graduate work, but to do so would make my discussion as lengthy as the paper.

My second premise is that the engineers who are the leaders in the profession at the time our present college men reach middle life will include many who have taken graduate work even unto the doctorate degree and that the next generation of engineers following these men will find graduate work almost absolutely essential to leadership, to the same degree as it has been so found by physicians, physicists, chemists, mathematicians, biologists, attorneys, and others, all of whom have found that the men occupying the better positions and enjoying the greater professional prestige are the men who for the most part have continued graduate work over a sufficient period to warrant the acquirement of a doctorate degree.

If Mr. Morrow's paragraph which reads as follows:

> As a general conclusion we may say that present graduate work is without completeness or unity in plan or policy; is taught by overworked or incompetent teachers; is without adequate experimental facilities, has relatively few students enrolled and only a few of these are qualified to do the work. We have few reasons to base plans for graduate training upon present experience and practice. There are sound reasons, however, for studying the present situation and building upon the good things found in past experience.

in general is correct, I would like to call attention to the fact that there are a number of engineering colleges to which the statements in that paragraph do not apply. Those colleges have not tried to offer graduate work for large numbers nor have they provided graduate engineering courses until after outstanding science and mathematics departments with courses available to engineering students had been well established. After having thus provided

these proper conditions for graduate work, the colleges I have in mind have established definite policies for graduate work which include unified and complete courses taught by competent and not overworked teachers provided with adequate experimental facilities in the way of laboratory space and equipment. To me it is perfectly clear that colleges which cannot arrange such a graduate program should not undertake engineering graduate work at all, or at least should not plan for more than one year of such work. I make the special classification regarding the one-year course because one year of graduate work, as has been stated, can well be along lines of the undergraduate engineering work, which does not demand correlated extensive graduate science and mathematics courses.

Particularly during the recent ten depression years a year of graduate work has had great value in making a way to employment possible for many men who could not obtain any satisfactory engineering positions at the end of their four-year courses, but who developed greatly during a year of graduate work and obtained at the end of their fifth year in college good engineering positions in places which seemed entirely closed to them at the time of graduation from the undergraduate courses.

## Leonard F. Fuller FELLOW AIEE

Mr. Morrow's views are idealistic, as he says, and rightly so, for that attitude is required for progress in the complex problems of education. The continued interest of the engineering profession in the training of young engineers is necessary for the guidance of the educators upon whom rests the responsibility for final decisions in such matters. Because of his teaching experience, Mr. Morrow speaks from first-hand knowledge and impressions, and his ideas are worthy of the most thoughtful consideration. I hope his article will occasion widespread discussion among engineers and educators.

Surely there will be general agreement that graduate study should be under competent men; that the physical plant should be of the best; that it is desirable for teachers of engineering to be active in the practice of their profession; and that some instruction should be by professors in departments outside the college of engineering, such as physics and mathematics. Undoubtedly the training of both undergraduates and graduates should be rigorous and broad within reasonable limits, for excessive specialization produces the man frequently referred to as having learned so much about so little that he knows nearly everything about nothing. But I do not think our leading engineering schools are failing to meet the situation. Present conditions do not justify serious concern over the shortcomings Mr. Morrow mentions.

Let us examine the facts that support this viewpoint and in doing so let us realize that graduate training is merely one of many steps in the life of a successful engineer who will continue to study to the end of his days. His college training, undergraduate and graduate, is primarily for the purpose of teaching him how to study and how to think in the ways that generations of engineers have found necessary and best. If he masters the fundamentals of engineering technology and approach and learns how to make intelligent use of libraries and the information obtainable from other men, the student is equipped to proceed thereafter with further study under his own power in whatever direction the practice of his profession may require.

In well-organized graduate schools, students now have ample opportunity to work under the best men in the departments of mathematics, physics, and chemistry as well as of engineering. In leading colleges the limitations to the graduate training of engineers are not the lack of proper courses, or laboratories, or men. Nor are they to be found in the better students themselves except for the fundamental fact that graduate study cannot, even under the most ideal circumstances, take the place of and develop a man as will the experiences and responsibilities of actual practice. By this I mean that the strongest of faculties, having at its disposal the finest of laboratory and library facilities, could not train the most carefully selected and brilliant students to be well rounded engineers in 4 years or 40 years of graduate study. We must not overlook the human factors of the student himself. Engineering training reaches the saturation point for the best students after three or four years of graduate work following the bachelor's degree. For most students the saturation point is reached much earlier, depending upon the scholastic abilities of the individual, and for many it is reached before the end of a four-year curriculum. The young engineer must transfer from the school of engineering or science to the school of life and engineering experience for continued progress. If he is the right man and has it in him, he will develop as an engineer and a leader of men. If he does not possess the necessary qualifications, he will not advance. His college studies and degrees are not substitutes for performance in industry. Graduate study cannot make him an experienced engineer.

For these reasons industry cannot offer the young man with graduate training, no matter how fine it may be, a starting salary much higher than that paid the four-year graduate, but the superior training of the young engineer with an advanced degree, if he possesses other necessary attributes, will assist him to demonstrate superior ability to his employer and to advance more rapidly in his chosen profession.

## Karl T. Compton FELLOW AIEE

After reading Mr. Morrow's article on this subject, I immediately admit two personal reactions: (1) I very largely agree with his general thesis, though not with all of the opinions which he quotes; (2) there are many points in Mr. Morrow's article which arouse in me an instinctive

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desire to discourse at length—a reaction which I shall hold in reasonable check. These reactions are a tribute to the stimulating character of the article.

Consider first the question of "market survey." Undoubtedly a survey of openings for engineers with postgraduate training is an important element in studying the desirable degree of participation by engineering schools in this aspect of engineering education. Such an analysis might show that the supply greatly exceeds the demand in mass, without proving that postgraduate work in some fields and for some types of men might not be the most important contribution which any engineering school could make. There are many situations, which can be easily called to mind, in which the employers are far behind the engineering educators in perspective and recognition of the opportunities and needs in industry. There are other cases in which this situation is reversed. The first point which I would make therefore is that any market analysis, to be of much value, would have to be carefully analyzed with reference to the needs and opportunities of particular situations by men whose vision is far beyond the average, and also that a detailed analysis and not a mere statement of average opinion or average conditions would be significant.

Certain facts of the real or potential market will, I think, be generally admitted. In some fields of engineering, as in the sciences, postgraduate training is now not only desirable but, for many kinds of work, is almost prerequisite. These are generally the types of engineering, like chemical, communications, and electrical, whose development on the heels of science has been most rapid. Other lines of engineering which have been more static, such as civil or mechanical engineering in their most common applications, are not so generally dependent upon more advanced academic training, and undoubtedly in a majority of cases practical experience at work is more valuable than postgraduate training in college except where the objective is some aspect of the profession which is more highly specialized, or developing more actively, or more dependent on mathematical and scientific background. If a mechanical engineer, for example, is to be a draftsman or a routine designer or operator of machinery, I see little value in graduate work; if he is to be an expert in fluid flow or strength of materials or the design and improvement of engines, then he can find in a good postgraduate department of mechanical engineering a great deal of valuable training which otherwise he could secure, if at all, only through disproportionate time and effort. My second point therefore is that the type of engineering activity toward which the student is headed (assuming his own inherent qualifications for this field) determines largely the degree of advantage of pursuing graduate work.

Another related consideration has to do with the organization of industry itself. In a highly organized industry like the telephone industry, the most valuable training for an engineer is probably in mathematics and physics, preferably including graduate work, and in the fundamentals of electrical engineering. The more specialized training for work in the company can be secured more competently and satisfactorily from the standpoint of the company after the young man has taken employment and through close association with the organized group of experts to which he is assigned. In a less highly organized industry however, such as the textile industry, there is relatively little opportunity for a young engineer to secure this type of specialized training from his associates, and here forward-looking educational institutions may provide training for certain advanced types of work far beyond anything likely to be available to the young employee in the industry. These facts again indicate that graduate training has a very important place to meet specific situations and that these situations may vary from decade to decade as industry develops.

Mr. Morrow stated that "there is a realization that the men now most active on the advance fronts of industry are the doctors in physics and chemistry." My observation has been that much of the most valuable research and training in the postgraduate engineering schools has been in the applications of physics and chemistry to the solution of engineering problems and the development of new engineering techniques. Extraordinarily satisfactory results have come from the infiltration of a few good research physicists or chemists into engineering departments where the co-operative attack on engineering problems jointly from the scientists' and engineers' points of view has been exceedingly fruitful. Graduate students, trained in such an atmosphere, have been found to be particularly valuable to industry in developmental work.

I have in mind a young man trained through postgraduate work as a mathematician and mathematical physicist, who then went on with postdoctorate study and research on the quantum theory of magnetism. In view of this highly theoretical background I was later very much interested to hear the head of the development laboratory of one of our great steel companies say that his people had secured more effective practical help from this young man than from any of their other consultants. I know of several other similar cases.

My conclusion is that postgraduate work in engineering can be exceedingly valuable for some situations and for some men. This is particularly true in the line of research and new development where no adequate alternative to postgraduate training exists. To some extent postgraduate training is also a practical necessity because the increasing demands for fundamental training in the sciences and the basic principles of engineering, combined with the enormously expanded scope of engineering knowledge, have made it necessary to go beyond the traditional four years of engineering education in order to secure a working knowledge of many branches of the subject.

If anyone really believes that there is not a market demand for engineers with postgraduate training, let him occupy for a while the presidential chair of an engineering school and talk to the continual succession of practical men from industry who come to request the establishment of specialized and therefore graduate courses in a far wider variety of subjects than any engineering school has considered it wise to undertake.

# North Eastern District Meeting and Student Branch Convention

FINAL DETAILS are being completed for the North Eastern District Meeting of the AIEE to be held at Springfield, Mass., May 3–5, 1939. Headquarters will be at the Hotel Kimball and arrangements have been made to house those attending in this hotel and other hotels in the city. Springfield, situated in the Connecticut River Valley, is the center of a growing and prosperous industrial area. An attractive program of entertainment, inspection trips, and technical sessions has been arranged by the District meeting committee under the chairmanship of W. O. Henschke.

### Entertainment

A stag smoker will be held Wednesday evening, May 3, at the Highland Hotel. An interesting speaker has been secured for this event and in addition a magician and a hypnotist have been scheduled on the program. A buffet luncheon also will be served.

On Thursday evening an informal mixed banquet will be held at the Hotel Kimball with Doctor John L. Davis as the principal speaker.

A women's entertainment committee is engaged in arranging entertainment for the women. A trip to Northampton with luncheon at Wiggins Old Tavern is planned for one day; a trip to Storrowtown is planned for another day; and a visit to the shopping district.

### Technical Sessions

Six sessions are being arranged. One of these is a general session with one or possibly two addresses by speakers of national prominence on economics or general subjects of nationwide importance.

Other sessions will deal with industrial power applications, power generation and air circuit breakers, power transmission, and selected subjects. Friday morning will be devoted to two student sessions in which papers will be presented by students from several of the universities and colleges within the District.

### Inspection Trips

The East Springfield works of the Westinghouse Electric and Manufacturing Company, the United States Armory, and the many varied industries in and about Springfield afford excellent opportunity for interesting and instructive insight into these industries. Tickets can be obtained at the registration desk and will be 25 cents for each trip; transportation will be provided for those desiring it, at no additional expense. The following schedule has been arranged:

**Wednesday afternoon, May 3**

1. *Bigelow Sanford Carpet Company, Thompsonville, Conn.* This plant, which is almost a hundred years old, manufactures a full line of rugs and carpets, and is one of the largest plants of its kind in the country.

2. *Stevens Paper Company, Westfield, Mass.* The plant that will be visited manufactures a high-grade kraft paper of extreme thinness, which is used principally as a solid dielectric in the manufacture of capacitors.

**Thursday afternoon, May 4**

1. *Chapman Valve Manufacturing Company, Indian Orchard, Mass.* This company has two electric furnaces which are used in casting special alloy steels, used in their valves. The furnaces will be in operation during the trip.

2. *Package Machinery Company, Springfield.* This company manufactures a varied line of packing and wrapping machines.

3. *United States Armory, Springfield.* The chief product made here has been the Springfield rifle, and the new semiautomatic rifle is now in production. In addition there is a large museum containing both early and modern weapons of all kinds.

**Friday morning, May 5**

1. *Westinghouse Electric and Manufacturing Company, East Springfield.* This plant manufactures a complete line of domestic and commercial refrigerators, air conditioning equipment, and small motors for fans, vacuum cleaners, and other appliances.

**Friday afternoon, May 5**

1. *Fisk Rubber Company, Chicopee, Mass.* This plant, which manufactures chiefly tires, also makes tape, belts, and other rubber products.

2. *Pratt and Whitney Aircraft Corporation, Hartford, Conn.* The various divisions of this corporation manufacture aircraft engines, propellers, and airplanes.

Those wishing to visit either the United States Armory or the Pratt and Whitney aircraft plant must signify their intention by Wednesday noon and be prepared to submit proof of citizenship by a birth certificate or other acceptable means. In lieu of a birth certificate, a certificate from a town clerk stating that the holder is a registered voter, an army or navy discharge certificate, a pilot's license, or a passport will be acceptable as proof of citizenship. Women will not be admitted to the Armory or Pratt and Whitney plant, but may visit the Armory Museum if a sufficient number is interested.

### Hotels and Registration

In an accompanying tabulation is given a list of the principal hotels in the city, together with the daily rates, European plan. Students may secure rooms at the

**Headquarters for the meeting are at Hotel Kimball, Springfield, Mass.**

YMCA, which is adjacent to the meeting headquarters, at $1.00 for one night or $1.50 for two nights. Members should make their hotel reservation directly with the management of the hotel they choose.

Advance registration will greatly assist the committees making arrangements and will avoid congestion on arrival. For this purpose an advance registration card will be sent to members in the District and nearby territory. A registration fee of $2.00 will be charged all nonmembers except Enrolled Students and the immediate families of members.

### Committees

**District Meeting Committee:** W. O. Henschke, *chairman;* C. L. Dawes, vice-president, AIEE; R. G. Lorraine, District secretary-treasurer;

**Hotel Rates in Springfield, Mass.**

| | Kimball | Highland | Charles | Bridgeway |
|---|---|---|---|---|
| Single—hot and cold water | $2.00, 2.50 | $1.50, 2.00 | $1.50, 2.00 | $1.50, 1.75 |
| Double—hot and cold water | 4.00 | 2.50, 3.00 | 2.50,3.00 | 2.50,3.00 |
| Single—with shower | | | | 2.00 |
| Double—with shower | | | | 3.00 |
| Single—with bath | 3.00 | 2.00–3.00 | 2.50, 3.00 | 2.50, 3.00 |
| Double—with bath | 5.00 | 3.50–5.00 | 3.50–4.50 | 3.50, 4.00 |

# Tentative Technical Program

Daylight Saving Time

**Advance copies of papers will be made available as papers are approved. If ordered by mail, price ten cents per copy; if purchased at Institute headquarters or at the meeting, price five cents per copy. The announcement of the meeting to be sent to members within the District and nearby territory will carry an order form for those who wish to order advance copies of papers.**

## Wednesday, May 3

### 9:00 a.m.—Registration

### 10:00 a.m.—Industrial Power Applications

**J. D. Wright,** presiding

TURBINE-ELECTRIC TEXTILE RANGE DRIVES, **E. L. Richardson,** General Electric Company.

CHARACTERISTICS AND POWER REQUIREMENTS OF SPINNING FRAMES, **E. A. Untersee,** General Electric Company.

ELECTRICAL EQUIPMENT ON MACHINE TOOLS, **B. P. Graves,** Brown and Sharpe Manufacturing Company.

### 2:00 p.m.—Power Generation

HYDROGEN-COOLED TURBINE GENERATOR, **D. S. Snell,** General Electric Company.

EXPERIENCE WITH HYDROGEN-COOLED TURBINE-GENERATORS, **M. D. Ross** and **C. C. Sterrett,** Westinghouse Electric and Manufacturing Company.

SOME FACTORS IN THE MECHANICAL DESIGN OF HIGH-SPEED TURBOGENERATORS, **S. H. Mortensen** and **J. J. Ryan,** Allis-Chalmers Manufacturing Company.

MECHANICAL PROBLEMS INVOLVED IN THE DESIGN OF TWO-POLE TURBINE GENERATORS, **C. M. Laffoon** and **B. A. Rose,** Westinghouse Electric and Manufacturing Company.

## Thursday, May 4

### 10:00 a.m.—General Session

**J. P. McKearin,** presiding

Arrangements are being made for two guest speakers of national prominence to deliver lectures preferably on economic subjects of nationwide importance.

### 2:00 p.m.—Power Transmission

**K. B. McEachron,** presiding

CARRIER-CURRENT LOSSES MEASURED AND INTERFERENCE MINIMIZED ON BOULDER-LOS ANGELES TRANSMISSION LINES, **J. D. Laughlin,** Bureau of Power and Light, City of Los Angeles, and **W. E. Pakala** and **M. E. Reagan,** Westinghouse Electric and Manufacturing Company.

DIELECTRIC STRENGTH OF PORCELAIN, **P. L. Bellaschi** and **M. L. Manning,** Westinghouse Electric and Manufacturing Company.

CORONA DISCHARGE ON RUBBER-INSULATED CABLES, **E. B. Paine, H. A. Brown,** and **W. P. Tyler,** University of Illinois.

CHARACTERISTICS OF RESTRICTED IONIZATION AND ITS RELATION TO VOIDS IN INSULATING MATERIALS, **C. L. Dawes,** Harvard University, and **P. H. Humphries,** Tulane University.

EQUIVALENT CIRCUIT IMPEDANCE OF REGULATING TRANSFORMERS, **J. E. Clem,** General Electric Company.

REGULATING TRANSFORMERS IN POWER-SYSTEM ANALYSIS, **J. E. Hobson,** Westinghouse Electric and Manufacturing Company, and **W. A. Lewis,** Cornell University.

## Friday, May 5

### 9:00 a.m.—Student Sessions

Professor E. M. Strong is arranging for two parallel student sessions, with student members presiding.

There will be a luncheon meeting for the Student Branch counselors and chairmen at the Highland Hotel immediately following this meeting.

### 2:00 p.m.—Selected Subjects

RECENT DEVELOPMENTS IN SPEED REGULATION, **C. R. Hanna, S. J. Mikina,** and **K. A. Oplinger,** Westinghouse Electric and Manufacturing Company.

MODERN TRENDS OF AIR CIRCUIT BREAKERS, **J. W. Seaman,** General Electric Company.

RADIO AS AN EMERGENCY MEANS OF BRIDGING GAPS IN WIRE TELEPHONE LINES, **J. G. Patterson,** New England Telephone and Telegraph Company.

TWO-PHASE CO-ORDINATES OF A THREE-PHASE CIRCUIT, **E. W. Kimbark,** Polytechnic Institute of Brooklyn.

THE RECTIFIER CALCULUS, **W. M. Goodhue,** Harvard University.

A NEW MEASURING INSTRUMENT FOR DIRECT CURRENT, **H. T. Faus** and **A. J. Corson,** General Electric Company.

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E. M. Strong, District chairman of student activities; F. A. Farrou, L. Wetherill, R. J. Underwood, C. E. Kilbourne, H. D. Griffith.

**Technical Program:** F. R. Longley, *chairman;* L. C. Packer, J. W. Bennett, A. L. Davis, O. A. Browne, C. D. Brainard, F. Rogers, O. L. Riggs.

**Student Sessions:** E. M. Strong, *chairman;* E. A. Walker, A. G. Conrad.

**Transportation and Trips:** R. E. Curtis, *chairman;* J. N. Alberti, J. W. Bennett, J. M. Newton, A. Blair, D. L. Ross, J. Carson, L. C. Packer.

**Entertainment:** B. W. Durfee, *chairman;* J. J. Finn, A. Blair, J. N. Alberti, J. M. Newton.

**Women's Entertainment:** Mrs. J. J. Finn, Mrs. L. P. Kongsted, Mrs. W. O. Henschke, Mrs. H. D. Griffith, Mrs. R. E. Curtis, Mrs. F. R. Longley, Mrs. F. E. Haskell.

**Hotels and Registration:** H. Passburg, *chairman;* J. N. Alberti.

**Publicity:** W. S. Scheering, *chairman;* R. R. Menard, Q. A. Brackett.

**Finance:** F. E. Haskell.

**CCIF 1936 Proceedings.** An English translation of the proceedings of the Comité Consultatif International Téléphonique at its eleventh plenary meeting in Copenhagen, Denmark, June 11–20, 1936, has been prepared and published by the technical staff of the International Standard Electric Corporation. The CCIF, an advisory body on which are represented telephone administrations throughout the world, is concerned with promoting and co-ordinating international telecommunication. Among the subjects considered at the 1936 meeting were important advances in carrier-on-cable, rating of telephone performance, and preparation of guiding principles for a general European toll-switching plan. The present volume deals specifically with changes and additions to the proceedings of the previous (Budapest 1934) meeting, without duplicating information already published. Other features are an index covering the 1936 and 1934 proceedings, a bibliography of over 1,200 English, French, and German publications, a list of CCIF recommendations in force January 1937, and a summary of recommendations made at the 1938 meeting in Oslo, Norway, many of which are already provisionally in force, pending approval in 1940. The book, uniform with preceding volumes, contains 338 pages, is priced at $2.50, and may be obtained from the general technical department, International Telephone and Telegraph Corporation, 67 Broad Street, New York, N. Y.

## Two Districts Announce Branch-Paper Awards

Prize for Branch paper was awarded by AIEE District 5 (Great Lakes) to Wendell C. Morrison (Enrolled Student) University of Iowa, for his paper "Synthetic Inductance," presented April 23, 1938, during a joint session of the District committee on student activities and the Tri-School (University of Illinois, Purdue University, and Rose Polytechnic Institute) Branch meeting, at Urbana, Ill.

By District 9 (North West) prize for Branch paper was awarded to Roy W. Warburton and W. Wallace Murdoch for their paper "An Investigation of Some of the Properties of a Non-Linear Circuit," presented at a meeting of the University of Utah Branch, May 23, 1938.

## Future AIEE Meetings

**South West District Meeting**
Houston, Texas, April 17–19, 1939

**North Eastern District Meeting**
Springfield, Mass., May 3–5, 1939

**Summer and Pacific Coast Convention (combined)**
San Francisco, Calif., June 26–30,1939

**Great Lakes District Meeting**
Minneapolis, Minn., September 27–29, 1939

**Middle Eastern District Meeting**
Scranton, Pa., October 11–13, 1939

**Winter Convention**
New York, N. Y., January 22–26, 1940

# Plans Progressing for AIEE Summer and Pacific Coast Convention

BY VIRTUE OF its location in San Francisco, Calif., the AIEE 1939 combined summer and Pacific Coast convention, to be held June 26–30, affords unusual opportunities to combine business and pleasure. The Golden Gate International Exposition, recently opened on Treasure Island in San Francisco Bay, will be the principal "extra curricular" attraction. (An article describing electricity's part in the operation of the exposition appears elsewhere in this issue.) The San Francisco Bay area is noted for its many beautiful homes, fine golf courses, and natural attractions such as famed Muir Woods, a virgin grove of giant redwoods. Within a day's drive are many noted resort areas including Del Monte and the Monterey Peninsula, Santa Cruz, Yosemite Park, Lake Tahoe, and the Redwood Highway.

The convention committee is making extensive arrangements for entertainment, sports, trips, and recreation. The business features of the convention will begin with the annual meeting of the Institute to be held Monday, June 26. This meeting will be followed by the conference of officers, delegates, and members, technical sessions, and a general session. The technical program tentatively arranged is broad in scope, embracing the following subjects: protective devices, communication, instruments and measurements, electrical machinery, power transmission and distribution, industrial power applications, electronics, basic sciences, research, automatic stations, lighting, and transportation. In addition, a joint session with the Institute of Radio Engineers is under consideration.

In addition to the foregoing, the 1939 convention will depart from the usual summer-convention tradition and will include student activities on the program. Two sessions are to be devoted entirely to student papers, and separate conferences to discuss student activities are being scheduled. Special accommodations for students will be available at reasonable rates. An unusual opportunity thus is being offered to students to participate in the convention, the inspection trips, and the entertainment features, and also to visit the many Pacific Coast attractions.

Entertainment for women guests is being planned by a special committee with Mrs. S. J. Lisberger as chairman. In addition to scheduled trips and entertainment, the women's committee will arrange, whenever requested, special parties to visit the Golden Gate Exposition, and for shopping, sightseeing, and bridge.

Convention headquarters will be in the Fairmont Hotel. Since hotel accommodations in the city are expected to be in great demand throughout the summer, because of the Golden Gate Exposition, members are urged to make early reservations. Accommodations and prices for the principal hotels in San Francisco are indicated in an accompanying tabulation, and also will be shown in a circular to be mailed to Institute members early in May. Members are urged to make prompt use of the coupon that will be part of that circular; those wishing to make earlier reservations should write directly to E. A. Crellin, Chairman, Hotel Committee, 245 Market Street, San Francisco, Calif., indicating the hotel of their choice, accommodations desired, date of arrival, and names of party members.

Further details pertaining to the convention program and its various features will be announced in the May issue.

**Golden Gate bridge from midspan, showing sodium-vapor luminaire and standard. The tops of the main towers are 746 feet above sea level**

**Principal Hotels in San Francisco, Calif., and Rates**

| Hotel | City Blocks From Headquarters | Single Room | Double Room | Suites |
|---|---|---|---|---|
| Fairmont | 0 | $4.00 to 8.00 | $6.00 to 12.00 | —— |
| Bellevue | 7 | —— | 4.50 to 6.00 | $10.00 to 12.50 |
| Mark Hopkins | Across street | 6.00 to 7.00 | 8.00 to 12.00 | 15.00 to 25.00 |
| Plaza | 5 | 5.00 | 6.00 | —— |
| Stewart | 5 | 3.00 to 3.50 | 4.50 to 6.00 | —— |
| St. Francis | 4 | 4.00 to 6.00 | 6.00 to 12.00 | —— |

All rates are per day for room with private bath. All hotels can easily be reached from headquarters by street car.

### Special Railroad Facilities

For those traveling from New England and the Atlantic Seaboard region the New York Central System offers special accommodations with connections at Chicago, Ill., and St. Louis, Mo. Arrangements can be made for going and returning via any of the diversified routes west of Chicago and St. Louis, and stop-over privileges can be arranged at almost any point desired. For full information and arrangements write to T. A. Smith, passenger representative, New York Central System, 466 Lexington Avenue, New York, N. Y. Special sleeping cars will be operated from New York to Chicago, picking up additional members en route, in the following schedules, for the exclusive use of members attending from the East:

**Wednesday, June 21, or Thursday, June 22**

**New York, N. Y., and Boston, Mass., to Chicago, Ill.**

*Commodore Vanderbilt*

Leave New York ..... 3:20 p.m.
Leave Harmon ..... 4:06 p.m.
Arrive Albany ..... 5:59 p.m.

Boston and Albany *New England States*

Leave Boston ..... 12:50 p.m.
Leave Worcester ..... 1:53 p.m.
Leave Springfield ..... 3:07 p.m.
Leave Pittsfield ..... 4:34 p.m.
Arrive Albany ..... 5:40 p.m.

*Commodore Vanderbilt*

Leave Albany ..... 5:59 p.m.
Leave Schenectady ..... 6:29 p.m.
Leave Utica ..... 7:55 p.m.
Leave Syracuse ..... 8:54 p.m.
Leave Rochester ..... 10:21 p.m.
Leave Buffalo ..... 11:25 p.m.

**Thursday, June 22, or Friday, June 23**

Arrive Chicago ..... 7:30 a.m.

### Connections at Chicago and St. Louis

The trains of the New York Central System connect at Chicago with all western railroads; the following selection of routes has been offered:

**Chicago and Northwestern—Union Pacific—Southern Pacific Route via Omaha and Ogden**

*Overland Limited*

Thursday, June 22, leave Chicago ..... 10:25 p.m.
Sunday, June 25, arrive San Francisco .. 8:25 a.m.

**Chicago, Burlington, and Quincy—Denver and Rio Grande Western—Western Pacific Route, via Denver, Gore Canyon, Salt Lake City, and Feather River Canyon**

*Exposition Flyer*

Friday, June 23, leave Chicago ..... 3:00 p.m.
Sunday, June 25, arrive San Francisco . 10:10 p.m.

**Santa Fe Route via Grand Canyon and Los Angeles**

*Grand Canyon Limited*

Thursday, June 22, leave Chicago ..... 10:00 a.m.
Saturday, June 24, arrive Grand Canyon 8:00 a.m.
Saturday, June 24, leave Grand Canyon. 8:20 p.m.
Sunday, June 25, arrive San Francisco .. 9:15 p.m.

**Chicago, Rock Island and Pacific—Southern Pacific Route, via Kansas City, Tucson, Phoenix, and Los Angeles**

*Golden State Limited*

Thursday, June 22, leave Chicago ..... 10:15 a.m.
Sunday, June 25, arrive San Francisco .. 9:00 a.m.

From St. Louis, Mo., roads with which connections are made are the Missouri

Pacific, Missouri, Kansas and Texas, Cotton Belt, Frisco Lines, and others.

CONVENTION COMMITTEE

The personnel of the 1939 summer and Pacific Coast convention committee is as follows: S. J. Lisberger, *general chairman;* D. I. Cone, *vice-chairman;* G. C. Tenney, *secretary;* R. O. Brosemer, *treasurer;* F. S. Benson, A. M. Bohnert, C. F. Bowman, C. B. Carpenter, O. B. Coldwell, P. M. Downing, C. E. Fleager, L. F. Fuller, L. R. Gamble, David Hall, N. B. Hinson, J. P. Jollyman, R. E. Kistler, H. J. MacLeod, J. A. McDonald, P. J. Ost, G. E. Quinan, C. E. Rogers, E. F. Scattergood, R. W. Sorensen, H. A. Stingle, and F. E. Terman. Subcommittee chairmen: M. S. Barnes, *registration;* R. J. Cobban, *sports;* H. W. Flye, *entertainment and reception;* E. A. Crellin, *hotel;* F. R. George, *trips and local transportation;* J. S. Moulton, *publicity;* Stanley Rapp, *transportation;* H. H. Skilling, *student activities;* and W. C. Smith, *program.*

## AIEE Executive Committee Meets at Headquarters

A meeting of the executive committee of the American Institute of Electrical Engineers was held at Insitute headquarters, New York, N. Y., March 6, 1939, in place of the regular meeting of the board of directors.

Present: John C. Parker, chairman, C. R. Jones, K. B. McEachron, and W. I. Slichter, members of the committee; C. R. Beardsley, director; H. H. Henline, national secretary.

Executive committee action on applications as of February 21, 1939, was reported as follows: 3 applicants transferred to the grade of Fellow; 8 applicants transferred and 5 elected to the grade of Member; 66 applicants elected to the grade of Associate; 79 Students enrolled.

A report of a meeting of the board of examiners held February 16, 1939, was presented and approved.

Disbursements in February, amounting to $27,448.57, were reported by Chairman Jones of the finance committee and approved.

Authorization was given for the organization of a Mansfield Section of the Institute.

Upon the recommendation of the committee on communication and the technical program committee, approval was given for the holding of a joint session with the Institute of Radio Engineers during the combined summer and Pacific Coast convention of the AIEE in San Francisco, June 26–30, subject to concurrence by the summer-convention committee.

As recommended by the standards committee, a Test Code for Apparatus Noise Measurement, which had been prepared under the auspices of the subcommittee on sound of the standards committee and was a revision of the test code which was printed in a preliminary form in the September 1937 issue of ELECTRICAL ENGINEERING, was approved for publication.

The executive committee confirmed the tentative acceptance by the president of an invitation to appoint a representative of the Institute to serve on a joint committee of leading military and professional societies, which was being organized for the purpose of holding a National Industrial Preparedness Dinner in New York on the evening of April 5, 1939. Past President F. B. Jewett was appointed by the president as such representative.

As requested by the Institution of Electrical Engineers, the national secretary was empowered to make the necessary arrangements for the presentation to Doctor W. D. Coolidge, at an Institute meeting, of the Faraday Medal, recently awarded to him by the IEE.

Report was made of the attendance of President Parker and National Secretary Henline at the annual meeting of the Engineering Institute of Canada, in Ottawa, Ont., February 14–15.

Other matters were discussed, reference to which may be published elsewhere in this issue or in future issues of ELECTRICAL ENGINEERING.

## AIEE Members Invited to World Automotive Congress

A coast-to-coast program features the 1939 World Automotive Engineering Congress of the Society of Automotive Engineers, in which AIEE members have been invited to participate. Opening in New York, N. Y., May 22, for a five-day session, the congress will proceed to Indianapolis, Ind., to attend the 500-Mile International Sweepstakes on May 30, hold meetings in Detroit, Mich., May 31 to June 2, and close with a three-day session in San Francisco, Calif., ending June 8.

Various aspects of aircraft development will be among the automotive engineering problems considered by the congress, with many of the papers presented by European authorities; 35 foreign governments and over 30 technical societies abroad have been invited to take part in the program.

The five-day technical program in New York will include sessions on aircraft, aircraft engines, fuels and lubricants, passenger cars, passenger car bodies, transportation and maintenance, trucks, busses, and railcars, Diesel engines, and tractor and industrial power equipment. No technical sessions are scheduled for the Indianapolis visit, but members will have opportunity to inspect the mechanisms of the cars that will take part in the race. At Detroit delegates will inspect operations at various automobile plants and attend a technical session at the General Motors proving ground. Sessions on aircraft, transportation and maintenance, fuels and lubricants, and Diesel engines will be held during the final three days at San Francisco.

Both the New York and San Francisco expositions are honoring the delegates to the Congress, May 24 having been designated "World Automotive Engineering Day" at the New York World's Fair, and the week of June 5, "World Automotive Engineering Congress Week" at the Golden Gate International Exposition.

Any Institute members interested in attending the congress may obtain detailed information from the Society of Automotive Engineers, 29 West 39th Street, New York, N. Y.

**A view in Cascade Valley, Calif., with Mt. Isaac Walton in the distance. This is typical of many scenic spots that may be enjoyed by those attending the AIEE 1939 combined summer and Pacific Coast convention**

## To Institute Members Planning Trips Abroad

Members of the Institute who contemplate visiting foreign countries are reminded that since 1912 the Institute has had reciprocal arrangements with a number of foreign engineering societies for the exchange of visiting member privileges, which entitle members of the Institute while abroad to membership privileges in these societies for

a period of three months and members of foreign societies visiting the United States to the privileges of Institute membership for a like period of time, upon presentation of proper credentials. A form of certificate which serves as credentials from the Institute to the foreign societies for the use of Institute members desiring to avail themselves of these exchange privileges may be obtained upon application to Institute headquarters, New York. The members should specify which country or countries they expect to visit, so that the proper number of certificates may be provided, one certificate being addressed to only one society.

The societies with which these reciprocal arrangements have been established and are still in effect are: Institution of Electrical Engineers (Great Britain), Société Française des Électriciens (France), Association Suisse des Electriciens (Switzerland), Associazione Elettrotecnica Italiana (Italy), Koninklijk Instituut van Ingenieurs (Holland), Verband Deutscher Elektrotechniker E. V. (Germany), Norsk Elektroteknisk Forening (Norway), Svenska Teknologföreningen (Sweden), Stowarzyszenie Elektrykow Polskich (Poland), Elektrotechnicky Svaz Ceskoslovensky (Czechoslovakia), The Institution of Engineers, Australia (Australia), Denki Gakkwai (Japan), and South African Institute of Electrical Engineers (South Africa).

## AIEE Members Invited to Paris Television Meeting

A meeting of a section of the Société Française des Électriciens for the presentation and discussion of a comprehensive series of papers on television by French engineers is to be held in Paris during a week in November 1939. The Société has invited members of the AIEE to attend the meeting and participate in the discussions. The papers will be published in the Bulletin of the Société after the meeting, and copies will be sent to American engineers who attend.

Institute members who expect to attend the meeting are requested to notify the national secretary who will transmit the information to Paris.

## 27 North Electric Men Apply for AIEE Membership

As an outgrowth of the formation of the Mansfield (Ohio) division of the AIEE Cleveland Section, 27 employees of the North Electric Manufacturing Company, situated in the neighboring city of Galion, have applied for membership in the AIEE. Names of the applicants were posted in the "Membership" department of the March issue.

When the Mansfield division was organized last December (*EE, Jan. '39, p. 39*) the five members of the Institute in the North Electric Company took a very active part in the new division's affairs. These five men, F. R. McBerty, H. F. Herbig, H. O. Whiteley, W. E. Ballentine, and J. M. Robinson, brought a number of the prospects to the meetings and helped to interest them in joining the Institute. When the membership drive got under way in the company, J. P. M. Blackhall, one of the applicants, headed up the activity, contacted all the prospects, and saw that all the blanks were filled out. It is noteworthy that Mr. McBerty, president of the company, was so vitally interested in the Institute that he arranged to have the company pay the entrance fee for each of the applicants.

When the Mansfield division was first organized there were 32 members in the area being served. Including the North Electric group, a total of 35 applications has been secured to date, bringing the total number of members and applicants in the Mansfield area to 67.

## AIEE Members Invited to High-Voltage Conference

Members of the AIEE have been invited to attend the tenth meeting of the International Conference on Large High-Voltage Systems (Conference Internationale des Grands Réseaux Électriques, called CIGRE) which will be held in Paris, France, June 29–July 8, 1939.

The 15 sessions, with no parallel sessions, will be devoted to the presentation and discussion of papers on the manufacture and maintenance of machinery, construction, and maintenance of stations and lines, interconnection, networks, and other problems in the generation, transmission, and distribution of electric power. Some 110 papers from 20 different countries will be presented and discussed during the nine days of the conference, which will be attended by some of the most eminent specialists from the various countries.

Membership in the conference is open to electrical engineers from all over the world, and full benefit of the papers and discussions will be available to any person speaking English, French, German, or Italian. The last meeting, which was held in 1937, was attended by 1,175 individuals from 46 countries. Institute members who expect to attend the 1939 meeting are requested to notify the national secretary, who will transmit the information to the headquarters in Paris.

**Committee Formed to Study Corrosion.** The American Co-ordinating Committee on Corrosion has been organized by a group of engineering and technical societies to serve as a clearing house for information on corrosion and its prevention. The committee, on which 18 societies are represented, was formed at a meeting held February 17, 1939, at the headquarters of the American Society for Testing Materials in Philadelphia, Pa. AIEE representative on the committee is H. S. Phelps (A'21) engineer, special investigation and testing division, Philadelphia Electric Company, Philadelphia, Pa. Permanent organization will be effected at the next meeting, to be held at Atlantic City, N. J., in June, during the annual meeting of the ASTM. C. L. Warwick, secretary-treasurer of the ASTM, is temporary chairman. The committee's first work will be the compilation of a list of those working in the field of corrosion in the United States, with information on their special interests and current programs of studies.

## Membership—

Mr. Institute Member:

It is gratifying to report that 705 new applications were received for membership during the month of February, of which applications 573 have come from Enrolled Students who have just begun their professional careers. At the time of this writing the returns continue to be satisfactory.

These returns indicate the great value the young engineer recognizes in the Institute and assure continued healthy growth of our organization.

I wish to express my sincere appreciation to every member who has in any way, large or small, through his personal feeling of loyalty and interest in furthering the advancement of our profession, assisted in encouraging some of these new members to affiliate themselves with the American Institute of Electrical Engineers.

L. L. Webb

Chairman, National Membership Committee

## Future Meetings of Other Societies

**American Electrochemical Society.** Spring convention, April 26-29, Columbus, Ohio.

**American Institute of Chemical Engineers.** 31st semiannual meeting, May 15–17, Akron, Ohio.

**American Institute of Mining and Metallurgical Engineers.** 22nd national open hearth convention, April 26–28, Cleveland, Ohio.

**American Physical Society.** 227th meeting, April 27–29, Washington, D. C.

**American Society for Testing Materials.** 42nd annual meeting, June 26–30, Atlantic City, N. J.

**American Society of Civil Engineers.** Spring meeting, April 19–22, Chattanooga, Tenn.

**American Society of Heating and Ventilating Engineers.** Semiannual meeting, July 4–6, Mackinac Island, Mich.

**American Society of Mechanical Engineers.** Semiannual meeting, July 10–14, San Francisco, Calif.

**American Society of Refrigerating Engineers.** Spring meeting, May 21–22, Hershey, Pa.

**Edison Electric Institute.** Technical committees meeting. May 1–4, Chicago, Ill.

Annual meeting, June 5–9, New York, N. Y.

**Institute of Radio Engineers.** Joint meeting with American Section of the International Scientific Radio Union, April 28 and 29, Washington, D. C.

**National Electrical Manufacturers Association.** May 14–18, Hot Springs, Va.

**National Fire Protection Association.** Annual meeting, May 8–12, Chicago, Ill.

**Society for the Promotion of Engineering Education.** 47th annual meeting, June 19–23, State College, Pa.

**Society of Automotive Engineers.** World Automotive Engineering Congress, May 22–28, New York, N. Y.; May 29–30, Indianapolis, Ind.; May 31–June 2, Detroit, Mich.; June 6–8, San Francisco, Calif.

## World Congress of Mathematicians

An International Congress of Mathematicians will be held in Cambridge, Mass., September 4–12, 1940, at the invitation of the American Mathematical Society. Headquarters of the congress will be Harvard University and Massachusetts Institute of Technology, and neighboring institutions also will co-operate. Support for the congress is being furnished by the Carnegie Corporation, the Institute for Advanced Study, the National Research Council, and the Rockefeller Foundation.

In addition to invited addresses and sectional meetings for presentation of short papers, the technical program will include conferences of specialists in fields of mathematics where important advances are currently in progress. Membership in the congress is open to all, at fees of $10 for regular membership and $5 for associate membership. Detailed information may be secured from the American Mathematical Society, 531 West 116th Street, New York, N. Y.

The first International Congress of Mathematicians was held at Chicago, Ill., in connection with the Columbian Exposition in 1893. Since then meetings have been held approximately every four years, except during the World War, but all have been in Europe, except the 1924 Congress which was held in Toronto, Ont., Canada. The average attendance at recent congresses has been about 600, representing some 40 countries.

## Physics Institute to Hold Temperature Symposium

Because so many of the methods used for measuring and controlling temperature in industry are electrical in nature, many AIEE members will be interested in a symposium on "Temperature and Its Measurement in Science and Industry" to be held under the auspices of the American Institute of Physics. Tentative plans are to hold the meeting from November 2 to 4, 1939, in New York, N. Y.

According to present plans, the primary purposes of the symposium are to: (1) coordinate the treatment of the subject in the sciences and branches of engineering; (2) review principles and bring up to date the record of recent work; (3) accumulate contributions for a comprehensive text, to be published as soon as possible after the symposium is held; (4) reveal the subject as an important branch of physics; and (5) supply schools with the information required for the improvement of curricula.

Those interested in taking part in this symposium should communicate with the American Institute of Physics, 175 Fifth Avenue, New York, N. Y., at an early date, giving information regarding their field of work and the subject of the contribution they wish to make. Such contributions will be co-ordinated with the subjects of a group of invited papers, and assignments and divisions made.

**Directory of Research Laboratories.** Data on 1,769 research laboratories of manufacturing firms and technical consultants are contained in the sixth edition of the directory of "Industrial Research Laboratories," recently issued by the National Research Council. The directory, NRC Bulletin Number 102, contains 270 pages, including indexes. The price is $2.50 in paper; $3.00 in cloth. Council headquarters are at 2101 Constitution Avenue, Washington, D. C.

# Current Items From American Engineering Council

## Incomes From Independent Professional Practice

The National Bureau of Economic Research has published a preliminary analysis of some of the results of a study of income from professional practice conducted over a period dating from 1929. The report is an intensive analysis of data collected by the Department of Commerce in its studies of national income.

Five professional groups are covered: Physicians and surgeons, dentists, certified public accountants, lawyers, and consulting engineers. The first section of the bulletin presents the average levels of net income in the five professions for a series of years. The most striking fact in this analysis is that the average income of consulting engineers, approximately a third higher than that of the next highest in the year 1929, drops sharply in three years to the lowest average income.

The average incomes of all the other four professions, while falling sharply with the exception of the dental profession, do not reach as low an average. This drop is noted in the report as follows:

> The precipitous fall in the incomes of consulting engineers relative to those received in the other professions is not surprising. To a far greater extent than in the other professions the demand for the services of engineers comes from industries notoriously subject to violent cyclical fluctuations in activity—the construction and heavy industries in general. And consulting engineers are in an even more vulnerable cyclical position than engineers as a whole, since their services are required in larger part in connection with the initiation of new projects or the expansion of existing enterprises
>
> The demand for the services of the other professions is much broader and is not concentrated in any one group of industries or final consumers. The broad pattern of change in their average net income resembles closely that in the average income from employment of all gainfully occupied persons.

## AEC Forum Proceedings Available

To meet the demand for copies of the AEC forum discussions, a limited supply of the proceedings on the six subjects presented and discussed last year are available as follows:

1. Employment and the Engineer's Relation to It—48 pages—15 cents.

2. Invention and the Engineer's Relation to It—48 pages—15 cents.

3. Public Affairs—Four Forums—64 pages—25 cents.

I—National Planning and the Engineer's Relation to It.

II—Economic Status of the Engineering and Kindred Professions.

III—Engineering Aspects of Government Reorganization.

IV—Engineering and Economic Factors in the Size of Business.

Over 2,000 copies of the proceedings of the first two forums have been distributed to government officials, public institutions, editors, and member organizations.

# Engineering Foundation

## New Monograph Published in Alloys of Iron Series

Latest addition to the series of research monographs on alloys of iron is "The Alloys of Iron and Nickel: Volume I—Special-Purpose Alloys" by J. S. Marsh, physical metallurgist and associate editor, alloys of iron research, The Engineering Foundation. Like its predecessors, it is published in New York, N. Y., by the McGraw-Hill Book Company for The Engineering Foundation, which is a joint agency of the Founder Societies. This monograph is the tenth in a series of critical summaries of technical information on iron and its alloys, prepared under the supervision of the iron alloys committee of the Foundation. Although the AIEE is not officially represented on the committee, Wilfred Sykes (A'09, F'14) of the Inland Steel Company, Chicago, Ill., is a member-at-large.

The amount of technical literature on iron-nickel alloys necessitated dividing the study into two volumes, the second of which is in preparation. The first deals with the constitution and properties of high-purity iron-nickel alloys and the properties of special-purpose alloys; the second will be concerned chiefly with the engineering properties of nickel steels and cast irons. A bibliography of more than 600 items is included in the present volume.

Of the 13 chapters, 4 are of particular interest to electrical engineers as dealing respectively with "Magnetic Properties of Iron-Nickel Alloys," "Magnetic Properties of Complex Iron-Nickel Alloys," "Mechanomagnetic Properties," and "Electric Properties." The author's preface points out that while much of the discussion is now of interest only to the communications industries, in time some of the materials considered may be used in power transmission also, if their higher cost as compared with present magnetic materials is overcome by greater efficiency.

# Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or reject them entirely.

ALL letters submitted for consideration should be the original typewritten copy, double spaced. Any illustrations submitted should be in duplicate, one copy to be an inked drawing but without lettering, and the other to be lettered. Captions should be furnished for all illustrations.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

## The Student Engineer and "Electrical Engineering"

As I have been reading the February ELECTRICAL ENGINEERING, I have been impressed with the thought that the requests of those members of the Institute who have been asking for a student page or section in ELECTRICAL ENGINEERING have been granted many-fold. Every article in the February number is of interest to and understandable by student engineers who have reached their senior year in college. Moreover, most of the material in this number is so free of dependence upon historic and mathematical background as to be readily appreciated and understood by, and even interesting to, every engineering student from the freshman class up. In fact, I think the number from cover to cover presents material of value to all who expect to be, now are, or have been engineers, be they freshmen, seniors, graduate students, technicians, designers, or executives. Moreover, ELECTRICAL ENGINEERING for a period of several months preceding the February 1939 number and dating back almost to the time of the adoption of the present publication policy, has contained papers of general interest for all engineers, younger and older alike.

ELECTRICAL ENGINEERING, in thus fulfilling the long expressed desire for more papers of interest to student engineers has, without the establishment of a special student section, achieved a goal of much greater value than the mere printing of the desired papers; this goal being the elimination of the appearance of a barrier between student engineers and practicing engineers who are known as Associates, Members, or Fellows. In other words, should we not endeavor to free our minds of any ideas that tend to make engineers think that the profession of engineering comprises men who live a sort of "caterpillar-butterfly" life, one stage of which comprises student life and the other stage the life of the practicing engineer, with little in common for the two stages?

In speaking of the engineer in college I have used objectively the term "student engineers," rather than "engineering students," because I am of the opinion that student engineers should not consider their college years as a time of preparation for life, but rather should realize that the years spent in college are some of the richest years of their entire lives. Student engineers while in college have greater opportunity really to live at a higher level of ideals, ambition, tempo, and capacity for work and play than will be possible for most of them during the years between graduation and arrival at their goals of recognized professional proficiency.

My third-of-a-century's contact with student engineers leads me to believe that the student in an engineering college whose after-life proves him an engineer is not in college because he wants to be an engineer, but is in an engineering college because he is already an engineer with the engineer's craving for a better knowledge of engineering lore. Such being the case, should he not be taught that his college years are a part of his engineering life and not just preparation for a future engineering career?

Lest there be some readers who still feel that ELECTRICAL ENGINEERING should have a separate section for Student Branch papers and news, may I state that during the time I have been chairman of the committee on Student Branches, and before I fully realized all the present publication policy of ELECTRICAL ENGINEERING is doing for student engineers, I felt obligated to see to it that ELECTRICAL ENGINEERING print each month as much material of interest to student engineers as possible. Having gained, in my experience as a board member, a first-hand knowledge of the practical difficulties involved in having a separate student news department, I endeavored to establish informally, without such a department, the publication of news and papers designed particularly for student engineers. This endeavor took the form of requests to some members of the Institute for articles and papers written particularly for student engineers. In some instances I suggested the subjects for the papers, but always left opportunity for those of whom papers were requested for choice of subject matter. To date not one person thus invited to write a paper has seen fit to accede to the request made, though some of those who were requested to write these papers have during the current year been authors of papers which can be read with profit by all Institute members. The results of this experiment, together with my knowledge of previous similar efforts, have convinced me that a special student section—were it wise or, in the opinion of our members, necessary—could not depend upon practicing engineers for regular or perhaps even an intermittent supply of special papers prepared for students.

Also, I well recall the failure of previous attempts which have been made to gather from student engineers the material for such papers. In fact, my own experience includes knowledge of several unsuccessful endeavors on the part of student prize committees to assemble papers for competition for student prizes, regional and national.

Some advocates of a student department have not had in mind student papers or papers written particularly for students, but have thought that a report page telling of Branch meetings, with their attendance records, subjects discussed at the meetings, speakers available, and other matters of news nature would be of value, if published on a student page. As chairman of the committee on Student Branches, I receive weekly from Student Branch secretaries the reports of Student Branch meetings. As I have checked these over, I have noted with interest the similarity of meetings at the various colleges, the approximate con-

stancy of attendance, and other activities at the colleges, and have come to the conclusion that, interesting though all these are, the month-to-month account conveys the impression of a country-newspaper type of news item about as interesting as: "Mr. and Mrs. John Doe journeyed to Jimtown last Saturday and Sunday to visit their son Henry." In fact, if my memory serves me correctly, a few years ago there was a Student Branch section giving news of this type which soon received so little attention that the idea was abandoned.

As a concluding word, therefore, may I ask the readers of this letter to give thought to the fact that the pages of ELECTRICAL ENGINEERING are open to all of its members of whatever grade, student engineers included, who wish to submit material for publication; and to the idea of trying to create in the minds of our older engineers and student engineers alike, the realization that electrical engineers are engineers from the time they decide to enter engineering college, if not sooner, and so long as they live, think, and act as engineers in serving their fellow men through the practice of some phase of the electrical-engineering profession.

Yours very truly,
R. W. SORENSEN (A'07, F'19)

(Professor of electrical engineering, California Institute of Technology, and chairman, AIEE committee on Student Branches)

## The Paradox of Social Progress

*To the Editor:*

Three long letters to the editor in the February issue testify to the sustained interest in the problems presented by Doctor Doherty under the above title. The table of contents for the same issue bears witness to editorial appreciation of the widespread interest among engineers in similar problems. The January issue contained a valuable contribution by President Karl Compton of Massachusetts Institute of Technology on the same general theme, for which it might be profitable to coin one standard generic title. Under the same title might be grouped a large number of contributions to *Mechanical Engineering* in recent years. These addresses and articles by such a large number of leaders in the profession must command the careful attention and consideration of engineers, scientists, and educators.

There is one aspect of the general problem, which may be termed for purposes of reference "The Social Responsibilities of Engineers and Scientists" which seems to have received scant attention throughout the prolonged discussion. In the interests of brevity extended quotations may be omitted, so one taken from Doctor Doherty's article ("The Paradox of Social Progress") may be selected as a text.

> In any case we face the evident fact that, even with our present rate of technological development, the consequent growth in complexity of social relationships has already surged beyond our understanding.
> Each day reveals fresh evidence of this. Most of the councils in which important matters of national concern are being settled are not distinguished by a comprehensive understanding of the problems considered, and by rational thought. What does distinguish them are strategy, show of force, emotion, and oratory.

This summary diagnosis of a most unfortunate situation may be accepted as essentially accurate. It suggests to me one important contribution which scientifically trained engineers might make to alleviate the confusion in which their fellow citizens, trained otherwise, find themselves enmeshed.

Doctor Doherty might find a place for the missing factor by amplifying items 3 and 4 in his five-point summary, page 447, column 2, paragraph 3, ELECTRICAL ENGINEERING, November 1938:

> 3. The ability to organize thoughts logically and with purpose.
> 4. The ability to use the English language and thus express their thoughts effectively.

Much of the spectacular success credited to demonstrated achievements in the fields of science and engineering may be explained by the relatively easy exercise of these two abilities in relatively limited fields, in contrast with the greater difficulties encountered in the more complex fields of human affairs.

However, a more sanguine attitude toward the future may be maintained by remembering that in one field of human affairs these same two abilities have played a conspicuous part in the development of civil law; and that, for centuries at least, civil law is perhaps the most continuous and reliable thread upon which advances in civilization have been strung. In order to complete the outline of "The American Dream" in his closing paragraph perhaps Doctor Doherty might have added a tribute to two essential factors in American cohesive progress. These are the Constitution of the United States and the institution and history of the Supreme Court. To these two factors a group of farseeing and well-educated men entrusted the future of the nation, and their foresight has been justified and endorsed by history. They exercised the abilities indicated in 3 and 4 with wisdom, and with a courage which did not take refuge under a plea of the complexity of human affairs. It seems to me that the engineering profession has been somewhat timorous in following that courageous leadership.

While freely recognizing the values of unambiguous precision in natural laws and their expression, in conventional units and standards in patents, in specifications and in contracts, they have not managed to sell their belief in their tools to nontechnical contemporaries. Had engineers demonstrated more convincingly the extent to which the gifts which they brought to a prospering civilization were dependent upon the rigorous technique to which engineers and scientists must perforce adhere in their dealings with natural laws perhaps the "strategy, show of force, emotion, and oratory" of which Doctor Doherty complains might not have attained their present preponderance in "the councils in which important matters of national concern are being settled."

The unique value of the "engineering approach" to such matters will not be convincing to the nontechnical until the leaders of thought with engineering and scientific training demonstrate that, in nontechnical as in technical matters, they can co-operate in presenting a single united front as spokesmen of the profession.

Without awaiting a plausible pretense of infallibility, or even of complete unanimity, they must be prepared to speak with one authoritative voice on the basis of the best premises available in the form of temporarily undisputed facts, even if these must be adopted by convention as are technical standards.

No exposition, however logical, can convince or receive lasting, reliable endorsement, which has not first secured agreement as to the premises upon which the exposition is based. This is the prerequisite from the omission of which the majority if not all of the contributions to this discussion seem to suffer. A promising and more truly scientific approach to the very interesting and important problem would start with a thorough co-operative effort to rectify the omission indicated.

Very truly yours,
CAMPBELL MACMILLAN (A'08, M'35)

(Research Engineer, Motor Department, General Electric Company, Schenectady, N. Y.)

## Technical Progress and Social Development

*To the Editor:*

Doctor Compton, in his article "Technical Progress and Social Development," states several principles of management. First: Management is an essential attribute of decent group life. Second: Wise management involves the minimum of control. "The problem today," he says, "is to determine the most advantageous balance between the two."

Assuming that such a point could be determined, how could the balance be maintained? Since the tendency is for management to expand its activities, such a condition of unstable equilibrium could only be maintained by a body having dictatorial powers. This would be in direct opposition to our accepted principles of government.

A less optimistic view is that of a society commencing with little or no management. The seed of management is planted and soon it flourishes, spreading its branches so that more and more phases of the society come under its influence. At some point in the development of the society, the elusive balance between control and freedom is reached and the "greatest number receive the greatest good." However, management continues to flourish like a weed and soon its influence is universal. At first the members of the society seek relief from control in the small periods of freedom left them. Soon the burden is too great and they free themselves in one great determined effort only to plant the seed again in the new society which rises from the debris of the old.

The humor in the situation is that Man with his great vanity will not admit the inevitability of this cycle, and it is just as well for him that he does not.

Yours very truly,
IRWIN HAUPT

(Electrical Engineer, 138 South Ninth Street, Philadelphia, Pa.)

# Personal Items

**J. F. Calvert** (A'27, M'35) has been appointed head of the electrical-engineering department at Northwestern University, Evanston, Ill. Doctor Calvert was born October 14, 1898, at Columbia, Mo. In 1922 he was granted a bachelor's degree and in 1924 the degree of electrical engineer from the University of Missouri. In 1930 he received the degree of master of science and in 1936 doctor of philosophy from the University of Pittsburgh. In 1923 he entered the training course of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and from 1924 to 1936 was employed in design and development work on large a-c machines with that company. From 1928 to 1935 he also served as a graduate lecturer in electrical engineering at the University of Pittsburgh. From 1936 to 1938 he was an associate professor at Iowa State College, Ames, before going to Northwestern University as professor of electrical engineering. He is the author or co-author of papers on various electrical-machinery subjects, and has been granted several patents concerned with high-voltage generators and machine protection from electrical transients.

**Shiv Narayan** (A'10, M'13) has retired from the principalship of the College of Engineering, Poona, India. Born in Delhi, India, in 1883, Professor Narayan received the bachelor of science and master of arts degrees from the University of the Punjab, Lahore, India, and from 1907 to 1909 was sent to the United States as a state scholar by the Jammu and Kashmir Durbar. During that period he worked in the testing department of the General Electric Company at Schenectady, N. Y., and attended Union College, from which he was graduated in electrical engineering in 1909. He served in the electrical department of the Jammu and Kashmir Durbar from his return from the United States in 1909 until his appointment as assistant professor of electrical engineering at the College of Engineering, Poona, in 1913. He was promoted to the grade of professor in the Indian Educational Service in 1920 and in 1938 he was appointed principal of The College of Engineering, a position which he held until his recent retirement. He is the author of four books in the field of electrical engineering. The trustees of Union College, Schenectady, N. Y., have recently voted him the honorary degree of doctor of science, to be awarded in June 1939.

**W. A. Furst** (A'13, M'27) has been appointed full-time co-ordinator of navy and maritime activities for the Westinghouse Electric and Manufacturing Company with headquarters at East Pittsburgh, Pa. A native (1892) of Maryland, Mr. Furst was graduated from the University of Maryland with the degree of bachelor of science in electrical engineering in 1912 and received the degree of electrical engineer in 1915. From 1914 to 1917 he was employed by the Consolidated Gas, Electric Light and Power Company of Baltimore, Md. He was an electrical engineer with the Emergency Fleet Corporation in Washington, D. C., and Philadelphia, Pa., from 1917 to 1919, when he was employed as an electrical engineer by the Lockwood Greene Company of Boston, Mass. Since 1920 he has been associated with the Westinghouse company, as general engineer, manager of the engineering division, Detroit, Mich., and manager, central engineering district, Pittsburgh, Pa. Before his recent appointment he was general contract manager at East Pittsburgh, Pa. He is currently chairman of the AIEE Pittsburgh Section.

**E. A. Casey** (A'27, M'31) has been appointed division manager for the West coast by Anaconda Wire and Cable Company. He will have headquarters at San Francisco, Calif., and supervision of the San Francisco, Los Angeles, Seattle, and Denver territories of the company. Born in Philadelphia, Pa., in 1897, Mr. Casey served in the World War and studied physics and mathematics at the Sorbonne, Paris, France, on a War Board permit in 1919. He received the degree of bachelor of science in electrical engineering at the University of Pittsburgh in 1925. Before becoming a sales engineer for Anaconda Wire and Cable Company, New York, N. Y., in 1929, he had been employed by Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., Union Switch and Signal Company, Swissvale, Pa., Duquesne Light Company, Pittsburgh, Pa., and American Brass Company, Waterbury, Conn. He has since been district engineer in charge of sales engineering for the eastern seaboard district of the Anaconda company, and before his recent appointment was district manager at Denver, Colo.

**Jesse Marsten** (A'26) has been appointed vice-president of the International Resistance Company, Philadelphia, Pa. He will continue in his capacity as chief engineer of the company. Born in Austria in 1897,

JESSE MARSTEN

Mr. Marsten received the degree of bachelor of science from the College of the City of New York in 1917. He was employed by the Marconi Wireless Telegraph Company of America from 1917 to 1920, working in the testing laboratory, engineering, and research departments. In 1923 he was employed in the technical department of the Radio Corporation of America, New York, N. Y., and in 1925 he entered the engineering department of Freed-Eisemann Radio Corporation, Brooklyn, N. Y. Later he was a radio engineer for the Earl Radio Corporation, Clifton, N. J., before becoming chief engineer for the International Resistance Company.

**H. W. Neblett** (A'15, M'21) has been elected a director of the Association of Iron and Steel Engineers. Mr. Neblett is engineer, new equipment design and application, Inland Steel Company, East Chicago, Ind. He attended Dickinson Normal College and studied electrical engineering at the University of Tennessee. In 1909 he entered the employ of the Lexington Railway Company, Lexington, Ky., as a repairman on cars and motors. In 1910 he went with the Commonwealth Edison Company at Chicago, Ill., as an operator of substations and served that company in various capacities until 1917. From 1917 to 1921 he was assistant electrical engineer with the Mark Manufacturing Company, Indiana Harbor, Ind., later going to the Chicago office as an electrical engineer with the Steel and Tube Company of America, successor to the Mark Company. From 1922 to 1928 he was engineer in charge of electrification with the Colorado Fuel and Iron Company, Pueblo, and from 1928 to 1932 he was head of the Neblett Engineering Company in Chicago. He became affiliated with the Inland Steel Company in 1932.

**E. A. Baldwin** (A'07) has been awarded the gold medal of the American Chamber of Commerce in France for distinguished service. Mr. Baldwin is vice-president and general manager of the International General Electric Company, Paris, France, and was president of the American Chamber of Commerce in France from 1934 through 1937. A native (1874) of Hyde Park, Mass., Mr. Baldwin was employed by the General Electric Company, Schenectady, N. Y., in 1896, after receiving the degree of bachelor of science from Massachusetts Institute of Technology. In 1899 he became an electrical engineer for the company's foreign department and was later made assistant manager of the department. Later he became manager of International General Electric, with headquarters at Schenectady. He has been vice-president at the Paris office for about ten years.

**C. R. Beardsley** (A'08, F'30) has been made manager of the contract control and inspection department of the Consolidated Edison Company of New York, Inc., New York. Mr. Beardsley was born in Bridgeport, Conn., in 1885 and received the degree of bachelor of philosophy in electrical engineering from Yale University in 1905. He was employed by the General Electric Com-

pany 1905 to 1911 at Schenectady, N. Y., New York, N. Y., and New Haven, Conn.; as sales agent by the United Illuminating Company, Bridgeport, Conn., 1911–18; and as electrical engineer by Fred T. Ley and Company, Springfield, Mass., 1918–23. He became electrical construction engineer for the Brooklyn Edison Company, Inc., Brooklyn, N. Y., in 1923, and later general superintendent of distribution construction. In 1938 he was transferred to Consolidated Edison of New York as assistant manager of the contract control and inspection department. Mr. Beardsley is a director of the Institute, and a member of several committees.

**A. H. Morton** (A'24) has been elected a vice-president of the National Broadcasting Company, New York, N. Y. He will continue as manager of the NBC operated stations department. A native (1895) of Chicago, Ill., Mr. Morton received the degree of bachelor of science from the University of Illinois in 1917. He served as lieutenant and later as captain of field artillery

A. H. MORTON

in the United States Army during the World War. In 1919 he was employed by the General Electric Company as an assistant to the chairman of the board, and from 1920 to 1921 was an assistant to one of the vice-presidents. He became Washington, D. C., representative of the Radio Corporation of America in 1921, commercial manager of RCA Communications, New York, in 1923, and European manager for RCA, with headquarters in Paris, France, in 1929. He returned to New York in 1934 to become business manager of the NBC program department, and assumed his present duties with NBC in 1937. Mr. Morton is a chevalier of the Legion of Honor.

**F. S. Haberly** (M'32) consulting engineer, has moved the permanent offices of his organization from Worcester, Mass., to Chicago, Ill. A native (1895) of Indiana, Mr. Haberly was employed by the General Electric Company, Fort Wayne, Ind., from 1914 to 1916, and then by the Fort Wayne and Northern Indiana Traction Company. After overseas service during the World War as an officer in the United States Army, he joined the staff of R. M. Feustel, consulting engineer, working on valuation of public utility property. During the next ten years he continued in valuation work for various utility companies and in 1929 became principal assistant in charge of valuation work for Albert S. Richey, consulting engineer, Worcester, Mass. At Mr. Richey's death in 1936, Mr. Haberly succeeded to his consulting practice.

**J. S. Murray** (M'31) has been elected a director of the Association of Iron and Steel Engineers. Mr. Murray is chief electrical engineer, Follansbee Brothers Company, Follansbee, W. Va. He started electrical construction work in 1913 for the Hellyer Electric Company, East Liverpool, Ohio. In 1915 he entered the employ of Moyers-Bennett Company, Wheeling, W. Va., as foreman of construction on electrification of the eastern coal fields. In 1917 he went with the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., working in the research and sales department. From 1919 to 1921 he did consulting engineering work at Pittsburgh, after which he was appointed electrical engineer for Follansbee Brothers at Toronto, Ohio. In 1928 he was placed in charge of all Follansbee plants.

**P. B. Garrett** (A'24, M'30) has been appointed northwestern district engineer of the Westinghouse Electric and Manufacturing Company, with headquarters in Chicago, Ill. After receiving the degree of bachelor of science in electrical engineering from Colorado State Agricultural College in 1922, Mr. Garrett entered the graduate student course of the Westinghouse company at East Pittsburgh, Pa. In 1923 he became a member of the general engineering department there, and in 1924 he was transferred to San Francisco, Calif., as general engineer for the west coast offices of the company. He was appointed engineering supervisor of the San Francisco office in 1927. Transferred in 1937 to the Salt Lake City, Utah, office of the Westinghouse company as engineering representative, he held that position until his recent appointment.

**Nathan Schnoll** (A'28) has organized Industrial Instruments, Inc., with headquarters at Bayonne, N. J. Mr. Schnoll is president and chief engineer of the new

NATHAN SCHNOLL

organization. A native (1904) of New York, N. Y., Mr. Schnoll attended the College of the City of New York. From 1922 to 1924 he was employed by the Western Electric Company, New York, as a tester, and for the following year did engineering research for Selco Radio Laboratories, joining the engineering department of F. A. D. Andrea, Inc., Long Island City, N. Y., in 1925. Later he became assistant chief engineer for Polymet Manufacturing Company, New York. Until his recent resignation he was chief engineer for Solar Manufacturing Company, New York.

**A. Y. Taylor** (A'37) has opened offices at Clayton, Mo., under the firm name of A. Y. Taylor and Company, consulting engineers. Mr. Taylor was graduated from Union College in 1929 with a bachelor of science degree in civil engineering, and later, took graduate work at Massachusetts Institute of Technology. In 1928 he was employed by the McIntosh and Seymour Corporation, Auburn, N. Y., as an erector of Diesel engines, and in 1929 was made tool designer and engineer. From 1932 to 1935 he did engineering work with the Potomac Electric Power Company, Washington, D. C. In 1936 he became associate engineer and later regional engineer with the Rural Electrification Administration in that city.

**David Levinger** (M'30) has been appointed assistant to the vice-president and works manager of the Hawthorne Works of the Western Electric Company at Chicago, Ill. A native (1887) of Idaho, Mr. Levinger was educated at Chicago Technical College, and was employed by International Harvester Company as a steel inspector for three years. In 1910 he went with Western Electric as a mechanical engineer, becoming assistant technical superintendent in 1920, assistant superintendent of development in 1922, and superintendent of manufacturing development in 1925. From 1928 until his present appointment he was engineer of manufacture.

**H. C. Hart** (A'33) has opened offices for the practice of patent law at New York, N. Y. Mr. Hart received a bachelor of arts degree from Princeton University in 1922, a bachelor of laws degree from Harvard University in 1925, and the degrees of bachelor of science (1931) and master of science (1935) from the University of Pennsylvania. From 1925 to 1928 he was engaged in the general practice of law in Philadelphia, Pa., and in teaching and research in electrical engineering at the University of Pennsylvania from 1931 to 1934. In 1935 he became associated with Pennie, Davis, Marvin, and Edmonds, New York patent attorneys.

**H. T. Faus** (A'24, M'34) development engineer, General Electric Company, Lynn, Mass., was one of 18 employees of the company to receive the Charles A. Coffin award for achievement in 1938. He developed a number of new instruments, including some for aircraft engines, which have commercial importance for the company. Mr. Faus, who received the degree of electrical engineer at Syracuse University in 1921 and was employed for the following year by the Simplex Surface

Contact Company, Williamsport, Pa., went to the West Lynn plant of General Electric as a student engineer in 1922.

**J. A. Johnson** (A'24) was honored at the annual banquet of the National Electrical Manufacturers' Association, held in New York, N. Y., February 9, 1939, with presentation of a certificate for 50 years of active service in the electrical industry. Beginning in 1888, Mr. Johnson was engaged in the installation and operation of electric plants in several Indiana communities. With E. Kuhlman, he founded the Kuhlman Electric Company, at Bay City, Mich., in 1894, and has served as its secretary, treasurer, general manager, and president, all of which offices except the first he now holds.

**Daniel Connolly** (A'37) has been appointed inspector of light and power in the department of water supply, gas, and electricity of the City of New York, N. Y. He was formerly employed by Maurice Scharf, consulting engineer, after completing a fellowship in the electrical-engineering department of the College of the City of New York.

**A. W. Robertson** (A'27) has been appointed chairman of the committee on national defense and industrial mobilization of The National Association of Manufacturers. Mr. Robertson is chairman of the board of the Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

**Dale Pollack** (A'37) has been awarded a Charles A. Coffin Fellowship by the General Electric Company for advanced scientific research. He will continue work toward his doctorate at Massachusetts Institute of Technology on a study of frequency modulation in radio communication.

**M. D. Hooven, Jr.** (A' 24, M'30) has been appointed assistant transmission and substation engineer of the Public Service Electric and Gas Company, Newark, N. J. Formerly a transmission engineer, Mr. Hooven has been with the company since 1922.

**W. W. Dunlop** (A'38) has been appointed junior engineer in the telephone and telegraph division at Beverly Hills, Calif., by the California Railroad Commission. He was formerly employed as installer by the Pacific Telephone and Telegraph Company at San Francisco.

**G. B. Thomas** (A'10, M'16) was elected vice-president of the Middle Atlantic section of the Society for the Promotion of Engineering Education for 1939. He is personnel director of Bell Telephone Laboratories, Inc., New York, N. Y.

**Hidemichi Rokkaku** (A'30) has been elected an editorial secretary of the Institute of Electrical Engineers of Japan for 1939 and 1940. He is an electrical engineer in the Electrotechnical Laboratory of the Ministry of Communications, Tokyo, Japan.

**J. V. Lamson** (A'29) is now an assistant engineer on the Bonneville Project, Portland, Ore. He was formerly an instructor in the college of engineering, University of Washington, Seattle.

**R. P. Ballou** (M'37) has become assistant development engineer in the electrical division of Colt's Patent Fire Arms Manufacturing Company, Hartford, Conn. He formerly was employed by the Allen-Bradley Company, Milwaukee, Wis.

**G. I. F. Theriault** (A'32) is now a welding engineer with the Frigidaire division of General Motors Corporation, Dayton, Ohio. He was formerly an electrical engineer with The Federal Machine and Welder Company, Warren, Ohio.

**Gano Dunn** (A'91, F'12) has been appointed to represent engineers on a committee to study the relation of civil service to legal and technical positions. He is president of the J. G. White Engineering Company, New York, N. Y.

**Ryoichi Masaki** (A'13) has been elected a vice-president of the Institute of Electrical Engineers of Japan for 1939. He is managing director of the Mitsubshi Electric Manufacturing Company, Ltd., Tokyo, Japan.

**B. F. Wells** (A'25) has been appointed assistant mechanical engineer at the Raritan Arsenal, Metuchen, N. J. He was formerly employed as an electrical draftsman by the Bureau of Power and Light, Los Angeles, Calif.

**Hideo Yamashita** (A'35) has been elected an executive secretary of the Institute of Electrical Engineers of Japan for 1939 and 1940. He is an assistant professor in the electrical engineering department of Tokyo Imperial University, Tokyo, Japan.

**F. D. Egan** (M'34) has been appointed chairman of the standardization committee of the Association of Iron and Steel Engineers for 1939. He is electrical superintendent of Bethlehem Steel Company, Lackawanna, N. Y.

**Wray Dudley** (A'12, M'15) has been appointed chairman of the welding engineering committee of the Association of Iron and Steel Engineers for 1939. He is electrical superintendent of National Tube Company, McKeesport, Pa.

**W. H. Taubert** (A'29) has been employed in the sales department of the Phelps Dodge Copper Products Corporation, New York, N. Y. He was formerly sales manager of the insulation division, Corning Glass Works, Corning, N. Y.

**H. S. Phelps** (A'21) will represent AIEE on the recently organized American Coordinating Committee on Corrosion. He is an engineer in the special investigation and testing division of the Philadelphia Electric Company, Philadelphia, Pa.

**H. W. Russell** (A'36) chief physicist, Battelle Memorial Institute, Columbus, Ohio, has been appointed to represent that institution on the recently organized American Co-ordinating Committee on Corrosion.

**Shoji Seto** (A'21) has been elected a vice-president of the Institute of Electrical Engineers of Japan for 1939 and 1940. He is professor of electrical engineering at Tokyo Imperial University, Tokyo, Japan.

**W. C. Morrison** (Enrolled Student) received the prize for Branch paper awarded by AIEE District Number 5 for his paper on "Synthetic Inductance." He is a student at the University of Iowa, Iowa City.

**J. C. Barry, Jr.** (A'36) formerly employed in the electric department of the City of Knoxville, Tenn., has been employed by the engineering department of the Illinois Iowa Power Company, at Champaign.

**R. E. Blasen** (A'34) has become a salesman at Spokane, Wash., for Westinghouse Electric and Manufacturing Company. He was formerly a sales assistant for the company at Seattle, Wash.

**J. B. Thomason** (A'38) has been employed as an engineer by the Harza Engineering Company, Charleston, S. C. He was formerly data engineer for Emerson Electric Manufacturing Company, St. Louis, Mo.

**W. S. Covington** (A'38) sales assistant for the Westinghouse Electric and Manufacturing Company, has been transferred from East Pittsburgh, Pa., to Baltimore, Md.

**Benjamin Parzen** (A'36) has been appointed junior electrical engineer at the Brooklyn Navy Yard, Brooklyn, N. Y. Formerly he was a radio inspector for the Federal Communications Commission.

**J. H. Marim** (A'38) student engineer for General Electric Company, has been transferred from Schenectady, N. Y., to Fort Wayne, Ind.

**D. C. White** (A'32) who has been equipment attendant at Grinnell, Iowa, for the American Telephone and Telegraph Company, has been transferred to Davenport, Iowa.

## Obituary

**James Delmage Ross** (A'08, M'10, F'12) administrator of the Bonneville Dam project, Portland, Ore., and superintendent of the Seattle, Wash., municipal power system, died March 14, 1939, at the Mayo Clinic, Rochester, Minn. Born November 9, 1872, at Chatham, Ont., Canada, and educated there, Mr. Ross began his engineering career as electrical engineer for the City of Seattle. He was in charge of the design, construction, and operation of the city's municipal power plant from its beginning in 1903, becoming in 1911 superintendent of the power system which grew under his management to a $50,000,000 undertaking. He was also a consulting engineer in Seattle, and in 1931 was called in consultation on power problems by the governor of New York State. Since 1933 he had been on leave of absence from the Seattle system, serving as advisory engineer for the United States Public Works Administration, Washington, D. C., until 1935, when he was appointed to the United States Securities and Exchange Commission, Washington, to handle registration of utility holding companies. In 1937 he resigned from the Commission to become administrator of the Bonneville project. He was chairman of the Seattle Section of the AIEE 1912-13.

**Austin Burt** (A'07, M'08, F'12) city manager and engineer, City of Ontario, Calif., died in September 1938, according to recent information. Born in Detroit, Mich., June 20, 1870, Mr. Burt studied engineering at the Universities of Wisconsin and Minnesota, and at Cornell University from which he received the degree of mechanical engineer in 1900. During the years when he was studying he was employed in engineering positions by Gillette-Herzog, Pillsbury Mills, and Spring Valley Iron Company, all of Minneapolis, Minn., and the Edward P. Allis Company in Milwaukee, Wis. For a quarter of a century he was associated with the development of electric service in Waterloo and Cedar Falls, Iowa, designing and constructing central stations and substations, high-voltage transmission lines, and having charge of operation. Starting as general manager of the Cedar Falls Electric Light Company, which merged with the Waterloo Company, Mr. Burt held engineering and executive positions in the combined companies through various organizational changes, being manager of the Citizens Gas and Electric Company of Waterloo until 1925, when he became vice-president of the Central Iowa Light and Power Company. He had held the position of city manager of Ontario, Calif., for about ten years at the time of his death. Mr. Burt was a member of Sigma Xi, and author of articles on technical subjects.

**James Lawrence McQuarrie** (A'07, F'26) retired, died at Vineyard Haven, Mass., March 1, 1939. He was born August 15, 1867, at Bath, Maine, where he received a high-school education. In 1882 he was employed as an operator by the New England Telephone and Telegraph Company, Boston, Mass., where he became successively inspector, manager, and engineer. He went with the Western Electric Company in 1894 and served as an engineer in New York and Chicago, becoming assistant chief engineer of the New York division in 1903. He was made assistant chief engineer of International Western Electric Company, New York, N. Y., in 1919 and chief engineer in 1925. In the same year the company became the International Standard Electric Corporation and Mr. McQuarrie was sent as chief engineer to London, England. When that organization was later merged with the International Telephone and Telegraph Company, he returned to New York as vice-president and chief engineer of the latter company, a position which he held until his retirement in 1935.

**Clayton Warren Pike** (A'91, M'92) consulting electrical engineer, died December 30, 1938, at Southern Pines, N. C. He was born in Fryeburg, Maine, July 11, 1866, and received the degree of bachelor of science in electrical engineering from Massachusetts Institute of Technology in 1889. He was employed as an electrical engineer by the Merrimac Manufacturing Company, Lowell, Mass., for a year, then was an instructor in electrical engineering for two years at the University of Pennsylvania, Philadelphia. He was employed in that city as an electrical engineer by Queen and Company in 1893–94, and by Falkenau Engineering Company from 1894 to 1900. For ten years he was vice-president and general manager of Keller-Pike and Company, Philadelphia. He was chief of the electrical bureau of the City of Philadelphia from 1912 to 1916, and for the remainder of his life a consulting engineer particularly concerned with public utilities. He was the author of books and articles on electrical engineering.

**Charles Appleton Terry** (A'87, M'87) honorary vice-president, Westinghouse Electric and Manufacturing Company, New York, N. Y., died February 18, 1939. Associated with the Westinghouse Company for half a century as legal counsel, Mr. Terry had handled details of many of the major basic patents of the electrical industry. He was born March 2, 1858, in South Weymouth, Mass., and graduated from Amherst College in 1879 and from Columbia University law school in 1883, specializing in patent law. During his law course he entered the law offices of Franklin L. Pope, patent attorney of New York, and later became a partner in the firm of Pope, Edgecomb, and Terry. In 1888 he joined the Westinghouse company and was head of the patent and legal departments during the struggle to establish the a-c system. Mr. Terry became vice-president of the company in 1909 and held the position until his retirement in 1931. He was a manager of AIEE from 1902 to 1905, and vice-president from 1905 to 1907.

**Joseph George Swallow** (A'09) retired consulting engineer of the former United Electric Light and Power Company (now Consolidated Edison Company of New York, Inc.), died in Pleasantville, N. Y., January 14, 1939. He was born in Manchester, England, August 25, 1851, and educated there. After coming to the United States he was employed in installation work by the United States Electric Light Company, Newark, N. J., and by the Jeffrey Manufacturing Company, Columbus, Ohio. He was employed by the United Electric Light and Power Company in 1889, and served as superintendent of installation for many years. In 1893 Mr. Swallow went to Chicago, Ill., as assistant engineer for the New York Insulated Wire Company, which wired the grounds of the Columbian Exposition. On his return he resumed his position with the United company. In 1922 he was assigned to the executive department as consulting engineer and continued in this position until his retirement in 1930.

**Carl Earnest Hardy** (A'99) superintendent, electrical department, City of Oakland, Calif., died February 15, 1939. Mr. Hardy, who was born in Rome, Ga., December 31, 1876, received the degree of bachelor of science in electrical engineering at Virginia Polytechnic Institute in 1897 and later graduated in mechanical engineering at Cornell University. From 1900 to 1911 he was employed as a government naval construction engineer, and for the next four years by Westinghouse Electric and Manufacturing Company in San Francisco, Calif. Appointed in 1915 as superintendent of the Oakland electrical department, he supervised installation of the city's traffic signal lights, police and fire signals, and street lighting system.

**Henry Herrman** (A'15) manager, thermometals department, The H. A. Wilson Company, Newark, N. J., died October 17, 1938, according to information just received at Institute headquarters. Mr. Herrman was born April 30, 1864, at Hamburg, Germany, where he attended school and college. Prior to his association with the H. A. Wilson Company, he was manager of the metals department at the Fort Wayne, Ind., works of the General Electric Company.

**Frederick M. Wilbraham** (A'19) consulting engineer for the Hartford Electric Light Company, Hartford, Conn., died January 21, 1939. Mr. Wilbraham was born in Hartford November 19, 1862, and entered the employ of the Hartford Electric Light Company as a switchboard operator in 1891, advancing by successive stages to the position of superintendent of power. For more than 15 years he had been a consulting engineer for the company.

**Oliver J. Morgan** (A'36) electrical inspector for the Delaware, Lackawanna, and Western Railroad Company, East Stroudsburg, Pa. died recently. Born November 18, 1892, at Madison, N. J., Mr. Morgan was associated with the Lackawanna road during most of his life.

# Membership

## Recommended for Transfer

The board of examiners, at its meeting on March 16, 1939, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

**To Grade of Fellow**

Holmes, H. A., planning engineer, Monongahela West Penn Public Service Company, Fairmont, W. Va.

Lovell, A. H., professor of electrical engineering and assistant dean and secretary, College of Engineering, University of Michigan, Ann Arbor.

Morgan, T. H., head, electrical engineering department, Worcester Polytechnic Institute, Worcester, Mass.

3 to Grade of Fellow

**To Grade of Member**

Dunlap, R. L., assistant engineer, Bell Telephone Company of Pennsylvania, Pittsburgh.

Evans, O. D., electrical engineer, Oklahoma Gas and Electric Company, Oklahoma City.

Gove, H. E., electrical engineer, Union Electric Company of Missouri, St. Louis.

Horton, H. M., district engineer, Oklahoma Gas and Electric Company, Oklahoma City.

Kinsly, N. T., superintendent of distribution, Tennessee Electric Power Company, Nashville.

Knaf, H. G., division engineer, Consolidated Edison Company of New York, Inc., New York.

Kulman, F. E., junior engineer, Consolidated Edison Company of New York, Inc., New York.
Laughlin, C. W., division transmission engineer, American Telephone and Telegraph Company, St. Louis, Mo.
Metcalfe, Donald, staff assistant, American Telephone and Telegraph Company, New York, N. Y.
Morgan, F. I., maintenance assistant, Pennsylvania Water and Power Company, Baltimore, Md.
Penney, G. W., manager, electro-physics division, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Southgate, G. T., consulting engineer, New York, N. Y.
Thomas, M. A., professor of electrical engineering, New Mexico State College, State College.
Torgersen, Harold, instructor, New York University, New York, N. Y.

14 to Grade of Member

## Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before April 30, 1939, or June 30, 1939, if the applicant resides outside of the United States or Canada:

### United States and Canada

Adamson, E. W., 622 Bellaire Avenue, Pittsburgh, Pa.
Agin, J., care of A. Koenigsberg Company, New York, N. Y.
Alexander, R. G., General Radio Company, Cambridge, Mass.
Altschuh, H., Jewel Incandescent Lamp Company, Newark, N. J.
Alworth, R. E., Public Utilities Commission, Boise, Idaho.
Ammann, W., Consolidated Edison Company of New York, Inc., New York, N. Y.
Anderson, E. L., Electro-Motive Corporation, La Grange, Ill.
Anderson, J. P., United States Bureau of Reclamation, Cody, Wyo.
Anema, G., Michigan State Highway Department, Lansing, Mich.
Aulick, B. W., Halliburton Oil Well Cementing Company, Houma, La.
Backus, W. A., Signal Corps Reserve, United States Army, Fort Monmouth, Oceanport, N. J.
Baily, A. L., West Penn Power Company, Washington, Pa.
Banta, F. D., International Business Machine Corporation, Endicott, N. Y.
Barcus, G. L., United States Bureau of Reclamation, Denver, Colo.
Barnes, W. J. (Member), Walter J. Barnes Electric Company, New Orleans, La.
Barrett, E. J., Sierra Pacific Power Company, Reno, Nev.
Barrows, M. D., Indiana and Michigan Electric Company, South Bend, Ind.
Bauer, J. L., United States Bureau of Reclamation, Denver, Colo.
Bean, C. L., United States Army, Vancouver, Wash.
Beard, C. I., Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.
Beckwith, E. F., 2011 West Erie Avenue, Lorain, Ohio.
Bedell, L., Bridgeman Electric Company, and Bridgeman General Contractor, Albuquerque, N. Mex.
Benham, T. A., Haverford College, Haverford, Pa.
Besier, A. P., Bell Telephone Laboratories, New York, N. Y.
Bilton, D. E., Bell Telephone Laboratories, New York, N. Y.
Bissey, L. J., 676 West Third Street, Loveland, Colo.
Bitonti, J. L., Ohio State University, Columbus.
Boggs, A. C., E. L. Wiegand Company, Pittsburgh, Pa.
Bowen, E. W., Pet Milk Company, Hudson, Mich.
Bradley, S. L., Halliburton Oil Well Cementing Company, Duncan, Okla.
Bradshaw, E. F., Murray Corporation of America, Detroit, Mich.
Brainerd, J. G. (Member), University of Pennsylvania, Philadelphia, Pa.
Brancato, E. L., United States Navy, Boston, Mass.
Brandt, P., Jr., Byron Weston Company, Dalton, Mass.
Braun, O. J., Amalgamated Electric Corporation, Ltd., Toronto, Ont., Canada.
Brettman, H., Rural Electrification Administration, Washington, D. C.
Bretz, G. W., Jr., 824 Highland Avenue, Bethlehem, Pa.
Brown, H. L., El Paso Electric Company, El Paso, Tex.
Brown, R. W., 1808 West Fifth Street, Sioux City, Iowa.
Browning, R. L., Jr., Black and Veatch, Kansas City, Mo.
Bruere, W. B. (Member), Portland General Electric Company, Portland, Ore.
Buehler, E. F., R. A. Donahue, Macomb, Ill.
Bullock, Roy, H. C. MacNary, New York, N. Y.
Bumpas, W. E., United States Bureau of Reclamation, Pavillion, Wyo.
Burkhart, J. R., General Electric Company, Schenectady, N. Y.
Busch, P. R., Rural Electrification Administration Lines, Winterset, Iowa.
Bush, R. L., Cannon Electric Development Company, Los Angeles, Calif.
Butler, N. O., Oklahoma University, Oklahoma City.
Campbell, J. A., care of James G. Cooney, Belleville, Ill.
Carroll, W. E., Illinois Bell Telephone Company, Lake Forest.
Caruthers, F. P., Jr., Phoenix Engineering Corporation, Houston, Tex.
Chapman, C. W., 810 South Philadelphia Street, Anaheim, Calif.
Ciesielski, J., Walter Scholer, Lafayette, Ind.
Clark, D. S., New York Telephone Company, New York, N. Y.
Claussen, F. B., Claussen and Claussen, Portland, Ore.
Clem, K., Control House, Chickamauga Dam, Chattanooga, Tenn.
Cloud, R. W., Massachusetts Institute of Technology, Cambridge, Mass.
Cochran, K. W., Iowa State College, Ames.
Coleman, A., United States Signal Corps, Oceanport, N. J.
Colin, R. J., Jr., Gooder-Henrichsen Company, Chicago, Ill.
Colvin, L. D., Pacific Gas and Electric Company, San Francisco, Calif.
Cooney, J. A., Hartford Electric Light Company, Hartford, Conn.
Cooper, J. E., 28 East Seventy-fourth Street, New York, N. Y.
Cooper, L. E., Railroad Commission of California, Sacramento.
Coronella, F. S., 103 Chambers Street, Boston, Mass.
Courtin, J. J., F. W. Woolworth Company, Germantown.
Cozine, H. E., 369 Third Street, Brooklyn, N. Y.
Crawford, C. S., Diboll, Kessels and Associates, New Orleans, La.
Cronk, L. H., North Road, Lancaster, N. H.
Crouch, C. A., Atchison, Topeka and Santa Fe Railway Company, Topeka, Kans.
Cully, J. F., Indiana and Michigan Electric Company, South Bend, Ind.
Curry, N., United States Motors, Inc., Los Angeles, Calif.
Curtiss, W. L., 2118 Ashland Avenue, St. Joseph, Mo.
Cushing, W. R., 432 East Court Street, Gainesville, Fla.
Dana, H. D., Electro-Motive Corporation, La Grange, Ill.
Darby, L. E., Indiana and Michigan Electric Company, South Bend, Ind.
Daubenheyer, H. W., Oklahoma Gas and Electric Company, Oklahoma City.
Davidson, E. R., Pacific Gas and Electric Company, San Francisco, Calif.
Davis, B., 682 Twenty-eighth Street, Oakland, Calif.
Davis, W., Piedmont and Northern Railroad Company, Greenville, S. C.
Day, R. P., Factory Insurance Association, Hartford, Conn.
Decker, F. S. (Member), College of Mines and Metallurgy, El Paso, Tex.
De Majo, J. J. R., Larmloc Corporation, New Orleans, La.
DeMar, J., 2053 Grace Street, Chicago, Ill.
Dempsey, J. J., Jr., 724 North Yakima Avenue, Takoma, Wash.
D'Hippolito, M. J., United States Army, Fort Dupont, Del.
Dittmann, W. L., University of Wisconsin, Madison.
Dod, A. B., Jr., Phelps Dodge Copper Products Corporation, Yonkers, N. Y.
Dole, A. R., Western Electric Company, Portland, Ore.
Donnelly, J. W., Consolidated Gas Electric Light and Power Company of Baltimore, Md.
Downing, C. R., Public Service Company of Oklahoma, Tulsa.
Draper, J. K., General Delivery, Casa Grande, Ariz.
Dravneek, W. R., Signal Engineering and Manufacturing Company, New York, N. Y.
Dunkelman, L., Portsmouth Navy Yard, Portsmouth, N. H.
Dunning, K. E., Western Union Telegraph Company, New York, N. Y.
Durkin, W. T., 318 West Henley Street, Olean, N. Y.
Eddy, M. H., Lincoln Electric Company, Cleveland, Ohio.
Edwards, E. A., Taylor Instrument Companies, Rochester, N. Y.
Efthim, C., 1016 Louisville Avenue, St. Louis, Mo.
Eiwen, C. J., Westinghouse Electric Elevator Company, Jersey City, N. J.
Ellis, W. C., New Orleans Public Service, Inc., New Orleans, La.
Emanuel, N., Pittsburgh Board of Public Education, Pittsburgh, Pa.
Emmer, A., Amperex Electronics Products, Brooklyn, N. Y.
Empey, R. W., State Geodetic Survey, Des Moines, Iowa.
Engel, F. A., Jr., 120 Cove Road, Hollidays Cove, W. Va.
Esselman, W. H., National Union Radio Corporation, Newark, N. J.
Evans, B., General Electric Company, Schenectady, N. Y.
Evans, D. J., 512 N. Jackson St., Hutchinson, Kans.
Feist, D. N., Warner Elevator Manufacturing Company, Cincinnati, Ohio.
Fisher, F. E., Appalachian Electric Power Company, Montgomery, W. Va.
Fleckenstein, E. L., Electrical Vocational High, Cincinnati, Ohio.
Flora, W. W., 900 W. 31st Street, Cheyenne, Wyo.
Ford, M. A., Indiana and Michigan Electric Company, Benton Harbor, Mich.
Foskett, D. B., Spreckels Sugar Company, Spreckels, Calif.
Frazier, J. F., Clarkson College of Technology, Potsdam, N. Y.
Friedman, T. B., Ward Products Corporation, Cleveland, Ohio.
Fullwood, H. S., United States Bureau of Reclamation, Wauwatosa, Wis.
Fulton, D. C., Jr., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Gaillard, R. L., 331 East Fourteenth Street, New York, N. Y.
Gaskin, G. C., Jr., University of South Carolina, Columbia.
Gates, C. F., General Petroleum Corporation of California, Bakersfield.
Gebel, I., International Register Company, Chicago, Ill.
Gerrish, D. L., Department of Public Works, New York, N. Y.
Gibson, J. E., Indiana and Michigan Electric Company, South Bend, Ind.
Giezentanner, R. B., Commonwealth Edison Company, Chicago, Ill.
Gilinson, P. J., Jr., Pacific Mills, Lawrence, Mass.
Gill, G. H., San Diego Engineering Laboratories, San Diego, Calif.
Gillette, L. H., Idaho County Light and Power Co-operative Association, Inc., Grangeville.
Gilliam, M. H., E. H. Gilliam Company, Charlotte, N. C.
Gise, L., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Goetz, G. A., Bethlehem Steel Company, Bethlehem, Pa.
Goff, P. C., Board of Fire Underwriters, Los Angeles, Calif.
Gottron, G. L., Bell Telephone Laboratories, Inc., New York, N. Y.
Graham, A. H., General Electric Company, Erie, Pa.
Gray, R. I., Nashua Manufacturing Company, Nashua, N. H.
Green, A. B., Duquesne Light Company, Pittsburgh, Pa.
Gregory, J. F., Springfield, Ky.
Griemsmann, J. W. R., Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
Griffiths, R. W., Bonneville Project, Hood River, Oregon.
Grimaldi, P. J., 1170 Gates Avenue, Brooklyn, N. Y.
Guglielmo, G. E., Paulina, La.
Hahn, E. R., Continental Can Company, New York, N. Y.
Haight, D. M., Route 6, Paola, Kans.
Haire, A. E., Tacoma Light Department, Tacoma, Wash.
Hale, N. H., Caterpillar Tractor Company, Peoria, Ill.
Halme, T. J., Canadian General Electric Company, Peterborough, Ont., Canada.
Hamburger, G., 111 (Member), Kennecott Wire and Cable Company, Chicago, Ill.
Hammond, J. W., Briggs Pump and Supply Company, West Lafayette, Ind.
Hanson, L. K., Electric Machinery Manufacturing Company, Minneapolis, Minn.
Harcid, D. T., Bell Telephone Laboratories, New York, N. Y.
Harris, B. G., Reliable Electric Company, Chicago, Illinois.
Harrold, W. T., KVI Puget Sound Broadcasting Company, Seattle, Wash.
Harter, V. J., New Jersey Bell Telephone Company, Newark.
Haverstick, J. S., DeLaval Steam Turbine Company, Trenton, N. J.
Hendry, A. J., Works Progress Administration, Detroit Lakes, Minnesota.
Herchenroeder, L. W., Iowa State College, Ames.
Hildebrand, R. L., Westinghouse Electric and Manufacturing Company, Cleveland, Ohio.
Hill, R. C., Indiana and Michigan Electric Company, South Bend, Ind.
Hill, W. A. (Member), Toledo Edison Company, Toledo, Ohio.
Hilliard, M. C., Southern California Edison Company, Ltd., Los Angeles.
Hino, K., 5646 Harper Avenue, Chicago, Ill.
Holt, C. O., Alvarado Telephone Company, Alvarado, Minn.
Horman, A. S., 118 Collins Avenue, Baltimore, Md.
Holmlin, H. W., Bell Telephone Laboratories, New York, N. Y.

Hornung, H. G., Ohio Power Company, Lima.
Hsu, C. P., California Institute of Technology, Pasadena.
Hudson, P. K., 31 Second Street, Athens, Ohio.
Huffman, M. M., Northern Indiana Public Service Company, Kentland.
Hughes, J. G., Duquesne Light Company, Pittsburgh, Pa.
Hulley, J. R., Gibbs & Hill, Inc., Parkers Landing, Pa.
Hunter, R. N., Bell Telephone Laboratories, New York, N. Y.
Ilgenfritz, L. M. (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Ipseu, S. J., 3749 Richmond Road, Richmond, Staten Island, N. Y.
Jenkins, R. J., Halliburton Oil Well Cementing Company, Mission, Tex.
Jepson, J. A., Central New York Power Corporation, Potsdam, N. Y.
Johnson, R. F., Black and Veatch, Kansas City, Mo.
Johnston, C. C., Mississippi State College, State College.
Johnstone, R. B., Electro-Motive Corporation, La Grange, Ill.
Jones, E. W., Cornell University, Ithaca, N. Y.
Jordan, B. B., Picker X-Ray Corporation, New York, N. Y.
Kauppi, K. O., Carnegie-Illinois Steel Corporation, Chicago, Ill.
Keithley, K. E., Texas-Empire Pipe Line, Tulsa, Okla.
Kelsey, S. G., Gausman and Moore, St. Paul, Minn.
Kessler, E. H., East Northport, N. Y.
Kiekhaefer, E. C. (Member), Kiekhaefer Corporation, Cedarburg, Wis.
Kinnebrew, W. E., Public Service Company of Oklahoma, Weeetka.
Kitzerow, D. J., Pressed Steel Tank Company, Milwaukee, Wis.
Klemesrud, H. L., 237 Sheldon Avenue, Ames, Iowa.
Korsan, W. E., The Louis Allis Company, Milwaukee, Wis.
Kosara, P. A., Jr., 164-27 Grand Central Parkway, Jamaica, N. Y.
Kurrias, J., New York Telephone Company, New York, N. Y.
Lacock, D. P., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Lake, C. J., National Union Radio Corporation, Newark, N. J.
Larsen, C. (Member), Light and Water Department, Lakeland, Fla.
Larson, L. A., Puget Sound Power and Light Company, Seattle, Wash.
Latzko, F. R. (Member), 558 West 189th Street, New York, N. Y.
Lees, A. R., Oliver Institute, Edmonton, Canada.
Leslie, M. W., University of Minnesota, Minneapolis.
Liberatore, D., New York City Department of Water Supply, Gas and Electricity, New York, N. Y.
Lindstrom, G. G., Electric Storage Battery Company, Philadelphia, Pa.
Linkletter, R. L., Puget Sound Navy Yard, Bremerton, Wash.
Lintern, A. J., Cleveland Electric Illuminating Company, Cleveland, Ohio.
Littlefield, H. Y., 311 South Craig Street, Pittsburgh, Pa.
Love, R. M., Durham Public Service Company, Durham, N. C.
Lovelace, B. A., 248 Worcester Road, Framingham, Mass.
Long, V. O., University of Colorado, Boulder.
Lundgren, C. W., Central Illinois Public Service Company, Mattoon.
Lutz, P. C., United States Navy, Washington, D. C.
Lynch, H. P., Bell Telephone Laboratories, Inc., New York, N. Y.
Mallach, L. W., Northwestern Electric Company, Portland, Ore.
Mann, P., Pacific Power and Light Company, Milton, Ore.
Mannal, C., General Electric Company, Pittsfield, Mass.
Manzavinos, A. T., 523 West 135th Street, New York, N. Y.
Markel, N. W., New Orleans Public Service, New Orleans, La.
Mattingly, R. L., Day and Zimmerman, Indiana, Pa.
McCabe, B. J., Poucher, Wood and Wallin, Inc., Poughkeepsie, N. Y.
McDonald, A. A., 1630 North Main Street, Los Angeles, Calif.
McElroy, W. C., Post Office Box 609, Greeley, Colo.
McMahan, W., Tennessee Valley Authority, Pickwick Dam, Tenn.
McMahon, E. V., J. B. McCrary Engineering Corporation, Atlanta, Ga.
McRoberts, C. E., Amalgamated Electric Corporation, Ltd., Toronto, Ont., Canada.
Menes, F. A., Jr., New York Telephone Company, New York, N. Y.
Merrell, C. M., City of Glendale, Calif.
Meyerhoff, L. (Member), General Cable Corporation, Perth Amboy, N. J.
Miller, J. B., Bucknell University, Lewisburg, Pa.
Miller, J. N., San Diego Consolidated Gas and Electric Company, San Diego, Calif.
Mirkin, M., Indiana and Michigan Electric Company, South Bend, Ind.
Moberg, C. V., Consolidated Gas, Electric Light and Power Company of Baltimore, Md.
Molinski, A. R., Bethlehem Steel Corporation, Johnstown, Pa.
Mohr, M. E., Bell Telephone Laboratories, Inc., New York, N. Y.
Moran, J. P., Consolidated Edison Company of New York, Inc., New York, N. Y.
Morgan, M. L., Tennessee Valley Authority, Knoxville, Tenn.
Morris, R. J., Bell Telephone Laboratories, Inc., New York, N. Y.
Morrow, G., Keystone Oil Burner Corporation, Brooklyn, N. Y.
Myers, J. S., General Electric Company, Schenectady, N. Y.
Nankervis, B. J., International Business Machines Corporation, Houston, Tex.
Netties, J. C., Hinckley's Electric Service, Monroe, La.
Neumann, A. J., 500 Riverside Drive, New York, N. Y.
Nevin, W. C., B-A-R-C Electric Co-operative, Millboro, Va.
Newberry, R. C., Otis Elevator Company, Springfield, Ohio.
Norman, F. F., Pacific Gas and Electric Company, San Francisco, Calif.
Nunan, J. K., University of Southern California, Los Angeles.
O'Connell, A. W., Ginn Electric Company, Cincinnati, Ohio.
Odenthal, L. P., 215 North St. Andrews Place, Los Angeles, Calif.
O'Donnell, A. J., Jr., Westinghouse X-Ray Company, Long Island City, N. Y.
Ottinger, C. F., United States Army, Coast Artillery Reserve, Fort Winfield Scott, Calif.
Parish, C. L., Monsanto Chemical Company, Columbia, Tenn.
Parsons, S., Consolidated Edison Company of New York, Inc., New York.
Patrick, R., Washington Water Power Company, Lewiston, Idaho.
Patterson, J. H., Ohio Power Company, Canton.
Perkins, P. E., Jr., New England Power Service Company, Worcester, Mass.
Perry, R. E., Route 2, Box 33 A, Manteca, Calif.
Phillips, C. V., 317 North Third Street, Marion, Kans.
Phillips, G. M., Bell Telephone Laboratories, Inc., New York, N. Y.
Phillips, R. E., Kansas Gas and Electric Company, Wichita.
Phillips, W. R., Jr., Route No. 3, Raleigh, N. C.
Phinney, J. H., United States Department of Commerce, Washington, D. C.
Pilcher, M. A., Kentucky and West Virginia Power Company, Inc., Ashland, Ky.
Pockel, C. A., Curtiss Propeller Division, Clifton, N. J.
Post, C. R., Western Electric Company, Inc., Washington, D. C.
Prather, T. C., Tennessee Valley Authority, Knoxville, Tenn.
Prichard, J. S., Western Pipe and Steel Company, Grand Coulee, Wash.
Pugh, H. F., Texas Company, Denver, Colo.
Quadrine, A. G., Lionel Corporation, Irvington, N. J.
Quayle, V. H., Quam-Nichols Company, Chicago, Ill.
Radcliffe, J. H., General Electric Company, Toronto, Ont., Canada.
Radmacher, L. N., Crown Willamette Paper Company, Camas, Wash.
Reinhardt, K. W., Socony Vacuum Oil Company, Inc., Olean, N. Y.
Ressa, J., Cambridge Instrument Company, Ossining, N. Y.
Reynolds, O. K., Jr., 624 East 220th Street, New York, N. Y.
Rhodes, J. B., Revere Copper and Brass Company, Rome, N. Y.
Rice, A. J., Material Laboratory, Navy Yard, New York, N. Y.
Richardson, H. D., Westinghouse Electric and Manufacturing Company, Belleville, N. J.
Rifkin, S., United States Bureau of Reclamation, Denver, Colo.
Roadcap, G. D., Missouri Valley Electric Company, Kansas City, Mo.
Roberts, F. C., General Electric Company, New York, N. Y.
Roberts, J. C., New York Shipbuilding Corporation, Camden, N. J.
Roberts, H. P., care of James G. Cooney, Belleville, Ill.
Robinson, J. M., North Electric Manufacturing Company, Galion, Ohio.
Rodgers, J. M., Delco Products Corporation, Dayton, Ohio.
Rombach, P. R., Jr., New Orleans Public Service, Inc., New Orleans, La.
Ross, A. K., Western Union Telegraph Company, San Francisco, Calif.
Rugg, P. J., Tennessee Valley Authority, Knoxville, Tenn.
Ruocco, W. P., Jr. (Member), General Electric Company, New York, N. Y.
Rushforth, G., Pacific Gas and Electric Company, San Francisco, Calif.
Rzeppa, T. S., Kames City, Tex.
Sahlman, F. M., 417 Twelfth Street, Cloquet, Minn.
Salvadge, C. H., Canadian General Electric Company, Peterborough, Ont.
Sayford, F. M., Jr., Frank M. Sayford Company, Brooklyn, N. Y.
Sayko, C. J., Standard Oil Company of New Jersey, Elizabeth.
Schaller, F. D., Picker X-Ray Corporation, Boston, Mass.
Scarborough, F. L., Tennessee Valley Authority, Chattanooga, Tenn.
Scheer, E. W., Jr., Bell Telephone Company of Pennsylvania, Philadelphia.
Scherf, P. H., Indiana Steel Products Company, Valparaiso.
Scherrer, G. M., A. Y. Taylor and Company, Clayton, Mo.
Schreiber, I. R., Virginia Public Service Company, Clifton Forge.
Schultheiss, C. E., University of Wisconsin, Madison.
Schultz, B. F., University of Oklahoma, Norman.
Scifres, R. E., Purdue University, West Lafayette, Ind.
Scott, E. E., Shell Petroleum Corporation, Shelbyville, Ill.
Seabury, R. L., General Motors Corporation, Muncie, Ind.
Seidman, G., 1519 Bouton Road, Troy, N. Y.
Shaffer, W. B., Power Equipment Company, Detroit, Mich.
Shannon, C. E., Massachusetts Institute of Technology, Cambridge.
Shellenberger, E. J., Halliburton Oil Well Cementing Company, Duncan, Okla.
Shelling, L., Boeing Aircraft of Canada, Vancouver, B. C.
Sherman, W. A., Narragansett Electric Company, Providence, R. I.
Shick, D. H., Illinois-Iowa Power Company, Bloomington, Ill.
Simpson, T. J., Engineering Research Corporation, Shreveport, La.
Sindeband, S. J., Consolidated Edison Company of New York, Inc., New York, N. Y.
Skootsky, H., State Relief Administration, San Francisco, Calif.
Slate, E. V., Department of Finance, Budget and Business, Olympia, Wash.
Smith, C. E., Indiana and Michigan Electric Company, South Bend, Ind.
Smith, C. R., General Electric Company, Schenectady, N. Y.
Smith, W. B., Bangor Evening School, Brewer, Maine.
Spielman, W. L., Baumes Engineering Company, St. Louis, Mo.
Sprague, W. R., University of Pittsburgh, Pittsburgh, Pa.
Stanhope, H. W. P. (Member), American Gas and Electric Service Corporation, New York, N. Y.
Steinhilber, T. H., Monsanto Chemical Company, Columbia, Tenn.
Stirling, H. H. (Member), Federal Power Commission, Atlanta, Ga.
Strohman, J. Y., 1901 Fairview Avenue, Easton, Pa.
Sturdevant, E. G. (Member), United States Rubber Company, Bristol, R. I.
Summers, F. R., Black and Veatch, Kansas City, Mo.
Sylvan, A. W., American Telephone and Telegraph Company, New York, N. Y.
Tallman, S. C., Bell Telephone Laboratories, New York, N. Y.
Taylor, G. E., Oklahoma Gas and Electric Company, Ardmore.
Tepper, C., United States Army, Fort Monmouth, N. J.
Theis, H. T., Day and Zimmerman, Inc., Philadelphia, Pa.
Thompson, B. V., International Telephone Development Company, Inc., Newark, N. J.
Thompson, W. L., Amber Electric Supply Company, Chicago, Ill.
Thumm, J. R., Lincoln Electric Company, Cleveland, Ohio.
Timbie, T. R., General Electric Company, Lynn, Mass.
Tolles, R. W., Stanley Works, New Britain, Conn.
Torian, J. T., R.C.A. Radiotron, Harrison, N. J.
Trim, Laurence O., City of Burbank, Calif.
Troxel, S. H., Jr., Philadelphia Electric Company, Philadelphia, Pa.
Troy, M. D., General Electric Company, Schenectady, N. Y.
Trubey, H. E., Jr., Trubey's Drug Store, Ellsworth, Kans.
Tuttle, A. D., New York State Electric and Gas Corporation, Hornell.
Uster, R. J., Jr., New York Telephone Company, Brooklyn.
Waligoski, A. A. (Member), Southern New England Telephone Company, New Haven, Conn.
Wallace, R. J., General Electric Company, Erie, Pa.
Ward, L. M., Southwestern Bell Telephone Company, Great Bend, Kans.
Ward, P. L., General Electric Company, San Francisco, Calif.
Waugh, D. L., 333 Crosby Street, Akron, Ohio.
Weathers, W. B., Westinghouse Electric Supply Company, Columbia, S. C.
Weber, P. J., Cooper Union Institute, New York, N. Y.
Webster, H. L., Fair Price Oil Company, Woonsocket, S. Dak.
Welker, J. W., Philadelphia Electric Company, Philadelphia, Pa.
Welty, R., Rural Electrification Administration, Washington, D. C.
Whaling, R. M., 835 Loring Avenue, Crockett, Calif.
White, J. A., Transmitter Equipment Manufacturing Company, Inc., New York, N. Y.

Whitman, L. C., General Electric Company, Pittsfield, Mass.
Wider, F. E., Board of State Harbor Commissioners, San Francisco, Calif.
Williams, E. A., Jr., Sperry Gyroscope Company, San Francisco, Calif.
Williams, N., 1144 Calumet Avenue, Calumet, Mich.
Wilson, H. R., Philadelphia Electric Company, Philadelphia, Pa.
Wilson, W. R., Elko Lamoille Power Company, Elko, Nevada.
Winn, V. C., Central Hudson Gas and Electric Corporation, Kingston, N. Y.
Wolf, E. F., Consolidated Gas, Electric Light and Power Company of Baltimore, Md.
Wood, H. B., 54 Le Moyne Avenue, Mount Lebanon, Pittsburgh, Pa.
Worona, N., Fort Hamilton, Brooklyn, N. Y.
Worthen, G. B., 385 Elm Street, Montpelier, Vt.
Worthen, P. W., General Electric Company, Schenectady, N. Y.
Woy, J. H., care of J. S. Hartt, Madison, Wis.
Wright, J. A., Puget Sound Power and Light Company, Seattle, Wash.
Wright, P. B., American Telephone and Telegraph Company, Phoenix, Ariz.
Wulfert, K. J., St. Louis County Health Department, Clayton, Mo.
Wynne, J. P., Western Union Telegraph Company, Denver, Colo.
Yadofsky, Z., 1710 Carroll Street, Brooklyn, N. Y.
Yokich, M., Box 14, Kinney, Minn.
Zimmerman, E. B., Chrysler Corporation, Detroit, Mich.
Zollinger, C., Indiana Bell Telephone Company, Indianapolis.

Total, United States and Canada—374

Elsewhere

Cadilla, J. A., Puerto Rico Distilling Company, Arecibo.
Correro, C. A., Cia Sole, Inc., San Juan, Puerto Rico.
di Lauro, J. J., Estudios San Miguel, Buenos Aires, Argentina.
Fernando, W. W. L., Messrs. English Electric Company, Ltd., Stafford, England.
Froome, W. J., Hawaiian Electric Company, Honolulu.
Lawyer, M. K., Water Works Department, Bombay Municipality, India.
Modi, J. T., Surat Electricity Company, Ltd., Surat, India.
Natarajan, K., Crompton Engineering Company, Ltd., Madras, South India.
Paton, J. E., Sydney County Council, Sydney, N. S. W., Australia.
Ringer, F. W., Lago Oil and Transport Company, Ltd., Aruba, Curacao, Netherlands West Indies.
Safra, J., Chark Apartment, Taksim, Istanbul, Turkey
Seifert, C. O., Jr., Apartado 81-Bis, Mexico, D. F., Mexico.
Sims, K. E., Borough of Finchley Electricity Undertaking, London, N. 3, England.
Vanvalen, D. M., Hawaiian Electric Company, Honolulu.

Total, elsewhere—14

# Engineering Literature

## New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, N. Y., recently are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface of the book in question.

THE REFRIGERATING DATA BOOK, Volume I. Refrigerating Principles and Machinery. Fourth edition. New York, American Society of Refrigerating Engineers, 1939. 527 pages. (Refrigerating Catalog and List of A.S.R.E. Members Section, 134 pages), illustrated, 10 by 6 inches, cloth, $4.00 in U. S. A., $4.50 in foreign countries. Brings together essential information and numerical data on refrigeration and air conditioning. An appendix gives a directory of equipment manufacturers and distributors, and a list of members of the society.

THE PERFORMANCE AND DESIGN OF DIRECT CURRENT MACHINES. (Engineering Degree Series.) By A. E. Clayton. Second edition. London, Sir Isaac Pitman & Sons; New York, Pitman Publishing Corporation, 1938. 445 pages, illustrated, 9 by 6 inches, cloth, $5.00. Explains the fundamental principles, load characteristics, control methods, efficiency, and testing of d-c machines. The mechanical construction and details are described with the aid of numerous illustrations, and detailed design information is given for various representative types of machines. A set of numerical examples for solution is included.

THE PERCEPTION OF LIGHT. By W. D. Wright. New York, Chemical Publishing Company, 1939. 100 pages, charts, etc., 8 by 5 inches, cloth, $2.50. A concise analysis of the visual phenomena of most importance to lighting engineers and others concerned with lighting problems. Special attention is paid to purely physiological investigations in this field. Among the topics considered are vision at low and high intensities, glare, and visual sensations.

PHYSIK. By P. Wessel and V. R. von Puar. Munich, Ernst Reinhardt, 1938. 514 pages, charts, etc., 8 by 5 inches, leather, 4.90 rm. This college textbook covers the customary topics included in physics courses.

Die ORTSFESTEN ANLAGEN ELEKTRISCHER BAHNEN. By K. Sachs. Zurich and Leipzig, Orell Füssli Verlag, 1938. 321 pages, illustrated, 11 by 8 inches, cloth, 20 rm., 48 Swiss frs. The construction of electric railways is presented with unusual detail in this treatise, which is based upon current practice throughout the world.

APPLIED GEOPHYSICS in the Search for Minerals. By A. S. Eve and D. A. Keys. Third edition. Cambridge, England, University Press; New York, Macmillan Company, 1938. 316 pages, illustrated, 9 by 6 inches, cloth, $4.25. The various exploratory methods now available: magnetic, electrical, electromagnetic, gravitational, seismic, radioactive, etc., are discussed theoretically and practically.

(The) ELECTROCHEMISTRY of GASES and OTHER DIELECTRICS. By G. Glockler and S. C. Lind. New York, John Wiley & Sons, 1939. 469 pages, illustrated, 9 by 6 inches, cloth, $6.00. This monograph, which was undertaken at the request of the Committee of Electrical Insulation of the National Research Council, brings together material on the behavior of liquids and gases in the electric field. Part one discusses the physical aspects of various kinds of discharge. Part two describes the reactions that have been studied. Part three discusses the underlying theory.

(The) ENGINEERS' MANUAL. By R. G. Hudson. Second edition. New York, John Wiley & Sons, 1939. 940 pages, illustrated, 8 by 5 inches, leather, $2.75. A collection of engineering formulas, mathematical operations, and tables that are constantly wanted by engineers and students of engineering.

FRACTIONAL HORSEPOWER ELECTRIC MOTORS. By C. G. Veinott. New York and London, McGraw-Hill Book Company, 1939. 431 pages, illustrated, 9 by 6 inches, cloth, $3.50. A treatment on fractional-horsepower motors; 18 major types are described, the descriptions explaining their principles of operation, usual forms of construction, performance characteristics, methods of connection, repairing, rewinding, testing, etc.

GMELINS HANDBUCH der ANORGANISCHEN CHEMIE. Eighth revised edition. Edited by Deutsche Chemische Gesellschaft. EISEN, Teil D. 1. Ergänzungsband. MAGNETISCHE und ELEKTRISCHE EIGENSCHAFTEN des EISENS und SEINER LEGIERUNGEN. System-Nummer 59. Berlin, Verlag-Chemie, 1937. 148 pages, illustrated, 10 by 7 inches, paper, 18 rm. New information is presented upon the electric and magnetic properties of iron and its alloys, especially the alloy steels.

KEMPE'S ENGINEER'S YEAR-BOOK 1939. 45th annual issue. Revised under the direction of L. St.L. Pendred. London, Morgan Bros., 1939. 2,824 pages, illustrated, 7 by 5 inches, leather, 31s. 6d. An annual British publication covering modern practice in civil, mechanical, electrical, marine, gas, aero, mine, and metallurgical engineering.

SPONTANEOUS FLUCTUATIONS of VOLTAGE, Due to Brownian Motions of Electricity, Shot Effect, and Kindred Phenomena. By E. B. Moullin. Oxford, England, Clarendon Press; New York, Oxford University Press, 1938. 251 pages, illustrated, 10 by 6 inches, cloth, $6.00. A study of fluctuations in electric circuits caused by thermal agitations of free electrons in conductors or by their random emission from hot surfaces. Based upon personal experimental work, this book summarizes present knowledge concerning these phenomena.

THEORY and APPLICATIONS of ELECTRON TUBES. By H. J. Reich. New York and London, McGraw-Hill Book Co., 1939. 670 pages, illustrated, 9 by 6 inches, cloth, $5.00. This book is intended to give the student, in one volume, a sufficiently thorough grounding in the fundamental principles of electron tubes and associated circuits to enable him to apply electron tubes to the solution of new problems.

RAILWAYS TO-DAY. (The Pageant of Progress.) By J. W. Williamson. London and New York, Oxford University Press, 1938. 160 pages, illustrated, 9 by 6 inches, cloth, $1.50. A concise yet comprehensive description of the modern railway, based upon British practice.

(A) TREATISE on LIGHT. By R. A. Houstoun. New York and London, Longmans, Green & Co., 1938. 528 pages, illustrated, 9 by 6 inches, cloth, $4.50. Sections treat geometrical optics, physical optics, spectroscopy and photometry, and mathematical theory.

ATM (Archiv für technisches Messen), Lieferungen 88–90, October–December 1938. Munich & Berlin, R. Oldenbourg. Illustrated, 12 by 8 inches, paper, 1.50 rm. each. Three numbers of a monthly publication containing classified articles upon various types of apparatus and methods for technical measurements.

ALL ABOUT SUBWAYS. By G. Conklin. New York, Julian Messner, 1938. 212 pages, illustrated, 9 by 7 inches, cloth, $2.50. Intended for young readers, this book tells in non-technical language the way subways are built.

CAPITAL CONSUMPTION and ADJUSTMENT. By S. Fabricant. New York, National Bureau of Economic Research, 1938. 271 pages, illustrated, 9 by 6 inches, cloth, $2.75. This report is a study of the records of capital consumption and adjustment in the United States since 1918.

FUNDAMENTAL PRINCIPLES of PHYSICS. By H. G. Heil and W. H. Bennett. New York, Prentice-Hall, 1938. 631 pages, illustrated, 9 by 6 inches, cloth, $5.00. Subjects usually found in an elementary text are here so arranged as to facilitate increasing use of the calculus in handling problems as the book progresses.

HIGH IRON, a Book of Trains. By L. Beebe. New York and London, D. Appleton-Century Co., 1938. 226 pages, illustrated, 11 by 8 inches, cloth, $5.00. A collection of photographs, with descriptive text, having historical association.

(An) Introduction to the THEORY of NUMBERS. By G. H. Hardy and E. M. Wright. Oxford, England, Clarendon Press; New York, Oxford University Press, 1938. 403 pages, illustrated, 10 by 6 inches, cloth, $5.00. Not a systematic treatise on the theory of numbers, this book comprises a series of introductions to the many sides of that theory.

KUNSTSTOFFE. Im Auftrage des Fachausschusses für Kunst- und Presstoffe des Vereines deutscher Ingenieure. Edited by F. Bobst and R. Vieweg. Berlin, VDI-Verlag, 1938. 92 pages, illustrated, 8 by 6 inches, paper, 3 rm. This brief treatise on artificial materials covers cellulose derivatives, synthetic resins and other plastics, and synthetic rubber.

PUBLIC UTILITY REGULATION. By G. L. Wilson, J. M. Herring, and R. B. Eutsler. New York and London, McGraw-Hill Book Co., 1938. 571 pages, tables, 9 by 6 inches, cloth, $4.00. An analysis of the nature, extent, and problems of public utility regulation is presented.

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## Papers Presented at Pacific Coast Convention, Portland, Ore., August 9–12, 1938

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|---|---|---|
| ☐ 38-43 | Lightning Arrester Subcom. | *Testing and Application of Lightning Arresters |
| ☐ 38-99 | Monroe | †Electrification of the San Francisco-Oakland Bay Bridge Railway |
| ☐ 38-100 | Whelchel | *Trends in Electrical Equipment in Hydraulic Power Plants |
| ☐ 38-101 | McMillan | *Polarity Limits of the Sphere Gap |
| ☐ 38-102 | Smith | *Use of Bismuth Bridge Magnetic Fluxmeter for A-C Fields |
| ☐ 38-103 | Shuck | *A Variable-Register-Ratio Watt-Hour Meter |
| ☐ 38-104 | Thomson | *Similitude of Critical Conditions in Ferroresonant Circuits |
| ☐ 38-105 | Morris | *Application of Copper-Oxide Rectifiers |
| ☐ 38-106 | Wagner | *Self-Excitation of Induction Motors |
| ☐ 38-107 | Ager | *Determination of Induction-Motor Performance |
| ☐ 38-108 | Dalziel | *Static Power Limits of Synchronous Machines |
| ☐ 38-109 | Peterson | *General Operation of Transmission Line |
| ☐ 38-110 | Cozzens & Peterson | *Corona Experience on Transmission Line |
| ☐ 38-111 | Cozzens | *Insulation and Lightning Protection |
| ☐ 38-112 | Laughlin | *Carrier-Current Equipment |
| ☐ 38-114 | Skellett | *Narrow-Band Transmission System for Animated Line Images |
| ☐ 38-115 | Norwine | *Controlling Amplitude Characteristics of Telephone Signals |
| ☐ 38-116 | Gaylord | *The Pumping System of the Colorado River Aqueduct |
| ☐ 38-117 | Skilling | *The Electrical Strength of Air at High Pressure |
| ☐ 38-118 | Pierce and Hamilton | *Phase-Angle Control of System Interconnections |
| ☐ 38-119 | Lyon | *The Electrostatic Unbalance of Transmission Lines |

## Papers Presented at Southern District Meeting, Miami, Fla., November 28–30, 1938

| | | |
|---|---|---|
| ☐ 38-124 | Kirkwood | Grading the Engineer's Job |
| ☐ 38-125 | Almond | Electrical Design of Pickwick Landing Project |
| ☐ 38-126 | Jones | Mulsifyre System for Extinguishing Oil Fires |
| ☐ 38-127 | Housley | Reconditioning of Insulating Oils by Activated Alumina |
| ☐ 38-128 | Stratton & Stratton | Shop Practice in the Repair of High-Voltage Bushings |
| ☐ 38-129 | George & Bessesen | *Generator Damper Windings at Wilson Dam |

## Papers Presented at Winter Convention, New York, N. Y., January 23–27, 1939

| | | |
|---|---|---|
| ☐ 38-122 | Putman & Dann | Loading Transformers by Copper Temperature |
| ☐ 39-4 | Morgan, Brown & Schumer | Determination of Stray Load Loss in Induction Machines |
| ☐ 39-5 | Potter | Measurement of Temperature in Squirrel-Cage Induction Motors |
| ☐ 39-6 | Hellmund | The Rating of Electrical Machinery and Apparatus |
| ☐ 39-8 | Brown & Cahoon | Amplifier-Wattmeter for Measurement of Watts and Vars |
| ☐ 39-11 | McDonald | Voltage Control of Mercury-Arc Rectifiers |
| ☐ 39-13 | Johnson | Predetermination of Tempesatures in Resistance Welds |
| ☐ 39-15 | Relay Subcommittee | High-Speed Relaying Experience and Practise |
| ☐ 39-17 | Lynn | Effects of Temperature on Rotating Electrical Machinery |
| ☐ 39-18 | Rutherford | The Rating and Application of Motors for Refrigeration |
| ☐ 39-19 | AIEE & EEI Committees | Bus Protection |
| ☐ 39-21 | Konn & Craton | Performance of the 3600-Hp New Haven Electric Locomotives |
| ☐ 39-22 | Kotterman | The Magnesium Copper Sulphide Rectifier Battery Charger |
| ☐ 39-23 | Seletsky & Zucker | Sensitivity of the Four-Arm Bridge |
| ☐ 39-24 | DeBellis | Modernization of Switch House Design |
| ☐ 39-26 | Strang & Hanna | Modernization of Switch House Design |
| ☐ 39-27 | Harder | Relay Protection of Pennsylvania Railroad Electrification |
| ☐ 39-28 | Caruthers | Copper-Oxide Modulators in Carrier Telephone Systems |
| ☐ 39-31 | Smith, Sonnemann & Dodds | Applying Ratio Differential Relays for Bus Protection |
| ☐ 39-32 | Stitcher & Thomas | Effect of Corona Discharge on Liquid Dielectrics |
| ☐ 39-33 | Kent & Blye | Inductive Co-ordination With Series Sodium Lighting Circuits |
| ☐ 39-34 | Ludwig & Grissinger | A New High-Capacity Air Circuit Breaker |
| ☐ 39-35 | Dickinson | "De-Ion" Air Circuit Breaker for Central-Station Service |
| ☐ 39-36 | MacNeill & Hill | Multiple-Grid Breakers for High-Voltage Service |
| ☐ 39-39 | Cox & Jones | Ignitrons for the Transportation Industry |
| ☐ 39-40 | Gray & Breyer | An Electronic Control Circuit for Resistance Welders |
| ☐ 39-41 | Ingram | Cold-Cathode Gas-Filled Tubes as Circuit Elements |
| ☐ 39-42 | Cassidy & Mosteller | Continuous Processing for Automobile Tire Fabrics |
| ☐ 39-43 | Smith | Electric Drives for Supercalenders in Paper Mills |
| ☐ 39-45 | Chu & Barrow | Electromagnetic Horn Design |
| ☐ 39-46 | Byrne | Polyphase Broadcasting |
| ☐ 39-47 | Dellinger | The Role of the Ionosphere in Radio Wave Propagation |
| ☐ 39-49 | Peterson | Power System Voltage Recovery Characteristics |
| ☐ 39-52 | Clarke, Crary & Peterson | Overvoltages During Power System Faults |
| ☐ 39-53 | Kendall & Affel | A 12-Channel Carrier Telephone System for Open-Wire Lines |
| ☐ 39-54 | Lawton | The Submarine Cable Plow |
| ☐ 39-55 | Nelson | The Submarine Cable Depthometer |
| ☐ 39-56 | Sorber & Smith | Remote Control Tollboard |
| ☐ 39-57 | Scudder & Reynolds | Crossbar Dial Telephone Switching System |
| ☐ 39-58 | Corney & Edson | Modernization of L Street Station Switch House |
| ☐ 39-59 | Hildebrand | Duty Cycles and Motor Rating |
| ☐ 39-65 | Roby | Simplified Precision Resistance Welder Control |
| ☐ 39-66 | Wright | Power Supply for Single-Phase Resistance Welders |
| ☐ 39-67 | Holslag | The A-C Arc Progresses |
| ☐ 39-68 | Kidder | Notes on Emergency Ratings |
| ☐ 39-69 | Thomas | Economical Loading of Underground High-Voltage Cables |
| ☐ 39-71 | Shanklin | Low Gas Pressure Cable |
| ☐ 39-72 | Lincoln & Sprole | Demand Meter Time Periods |
| ☐ 39-73 | Keinath | An Automatic A-C Potentiometer and Applications to Testing |
| ☐ 39-74 | Green | Aluminum-Nickel-Cobalt Brake Magnets for Watt-Hour Meters |

* These papers have been published in the Transactions section of Electrical Engineering.
† This paper has been published in the 1938 AIEE Transactions volume.

# Transactions

**Papers and Discussions Comprising Pages 131–78 of the 1939 Volume**


# Symposium on Operation of the Boulder Dam Transmission Line—General Operation of Transmission Line


By WM. S. PETERSON
MEMBER AIEE



**Synopsis:** The successful operating experience had during the first 1½ years with the Boulder Dam-Los Angeles transmission lines of the Department of Water and Power is reviewed in a symposium of five papers. Two unusually severe winter seasons and two lightning seasons, one of which was largely during the construction period, have served to test the line, so that an accurate judgment of its future performance can be made. An historical summary of the use of the line during permanent installation and adjustment of auxiliary equipment and through the period of normal operation to the present time is presented. The manner in which the electrical and mechanical performance has proved the design is developed and the unforeseen problems requiring solution are described. In addition to this general discussion, the excellent performance of the conductor from the standpoint of corona, the outstanding freedom from lightning flashover, are shown in two separate papers. Two additional papers describe the carrier-current supervisory and communication systems and the relay protection system as well as fully discussing the experience had in placing this equipment in adjustment and having successful operation.


THE Boulder Dam transmission line of the Department of Water and Power of the City of Los Angeles, has been in service since October 1936. By virtue of the vagaries of climate, the line has been called upon to withstand lightning, wind, ice, and floods of unusual severity, subjecting the line to many of the extreme conditions for which it was designed, without having to wait the usual long term of years for such conditions to occur.

This circumstance makes it particularly appropriate to review the performance of the line under such operating conditions, for a satisfactory judgment on its long-time performance can thus be made. To present this material together with any special or new problems that have required solution is the purpose of this symposium. It has been found advisable to present this material under several appropriate headings dealing with the mechanical and electrical characteristics of the line, corona, insulation and lightning protection, carrier-current equipment, and relay protection. Where the original description of certain features has not been given heretofore, as for carrier equipment and relays, they are included in these papers.

This line, operating at 287.5 kv, consists of two circuits, each 266.5 miles long, carried on two single-circuit steel-tower lines, except for 40.5 miles carried on double-circuit towers near Los Angeles. It includes such unusual features as 1.4-inch-diameter hollow copper conductor of the segmental type; special suspension clamps; high level of insulation provided by suspension insulator strings consisting of 24 ten-inch-diameter by five-inch-pitch porcelain units; two overhead ground wires, 30 to 40 feet above the conductors; two continuous buried ground wires or counterpoise wires per tower line, with interconnections between tower lines where single-circuit construction is used. Two intermediate sectionalizing switching stations are located at one-third points known as Silver Lake and Victorville stations. Operating as part of the receiving end line sections are two banks of autotransformers reducing the voltage from 275 to 132 kv at Century receiving station (station *B*).

The complete general description of the line and discussion of its various engineering features have been given in a paper entitled "Engineering Features of the Boulder Dam Transmission Line" by E. F. Scattergood,[1] in which paper, as well as in a companion paper,[2] there was indicated the unusual and urgent necessity for this line to be built so as to achieve the utmost reliability. With this object in view, liberal safety factors were employed, in its mechanical and electrical design, and a new step in high voltage was taken, together with the use of the two intermediate sectionalizing stations so that it could carry its normal rated load of 240,000 kw delivered, with unimpaired stability when subjected to two phase to ground faults, removed by dropping a section of circuit. This operating capacity was taken as 80 per cent of the theoretical limit, which was cal-

**Figure 1. Remains of double-circuit tower after flood**


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1. For all numbered references, see list at end of paper.

culated without including all of the system of the Department and is therefore also conservative. Factors in obtaining this performance were generators of liberal characteristics, and exceedingly rapid relays and circuit breakers, which would clear faults in approximately 0.1 second or less. The line has an emergency capacity of 300,000 kw delivered, a limit imposed by generator capacity.

The reliability that was built into the system was of outstanding importance when the system went into service. The necessity of making a frequency change cut-over from 50 to 60 cycles at the same time as the line was inaugurated, made the demand for its use so great that essentially the only test the new Boulder system received was the test of service. The very instant that the first Boulder power house generator was available, the transmission system went into service and has continued to give the type of performance anticipated, despite the extreme mechanical loading imposed by a winter remarkable for the worst cold, snow, sleet, and wind recorded during the history of the local weather bureau; followed, a year later, by the thorough test on line location and structural strength, given by a winter having the most severe floods within over 50 years.

## Preliminary Use of Line

The first application of normal voltage to a section of the line occurred on September 20, 1936, when a 90-mile section of one circuit from Los Angeles Century receiving station to Victorville switching station, was excited from the receiving end. This use of the line was made in connection with testing out and developing a neon-tube tower light obtaining its power from capacitive coupling with the line conductors.

The characteristics of the available equipment and transmission lines included in the circuit, and the resultant charging-current effects, made it impossible to build up voltage slowly on the new line, so that on closing the circuit breaker, the voltage immediately came up to normal. The charging kilovolt-amperes was 28,600 as predicted from the calculation of line and transformer constants. No difficulty was experienced with the line or the various circuit breakers and disconnects which were tested at the same time.

## Frequency-Change Considerations

A consideration of consumer's interests had indicated the desirability of changing the frequency on the Bureau of Power and Light system from 50 cycles to the 60-cycle standard used throughout the country. The bringing in of a relatively large new source of power made it desirable and economical to make the change-over when such power was available. Early estimates of generator availability had indicated that the frequency change could start in April 1936, and an organization was built up on that basis. Delays from that date were costly but necessary.

As the first Boulder generator unit did not finally become reliably available until October 22 and the second generator not until November 14, it becomes evident that the transmission system had to go into effective operation immediately as the generators became available.

## Operation for Inauguration

In accordance with anticipated availability of generator units, appropriate ceremonies pertaining to the arrival of Boulder Dam power in Los Angeles were set for October 9, 1936. Broadcasting and other program arrangements required adherence to this date. From the engineering standpoint this inaugural use of the line was important because it was the original tryout. Due to the co-operation of the government and the manufacturer, a generator was made available for that event, although it was not in condition to be released for regular service until nearly two weeks later.

Temporary arrangements of relay equipment and carrier telephone equipment were installed. Both power circuits were available but only one was used in order to avoid self-excitation of the generator.

The program included the use of a large arc to announce the arrival of Boulder power. Line and system arrangements were such that power from Boulder Dam would come over the south circuit, and thence through various system connections and series reactance to a 2,300-volt feeder to a downtown location, where arrangements were provided at the top of 70-foot poles for producing an arc between three-inch-diameter electrodes, arranged vertically, and separated approximately three feet. At the arc the voltage was approximately 1,000 volts, the current was 500 amperes, and the power consumed was 500 kw.

At 2:08½ p.m. October 9, the line was energized to the receiving station at low voltage and reduced frequency. No synchronous condensers were in use. Within three-quarters of an hour, the speed had been brought up to normal and the voltage on the generators was 75 per cent of normal in order to produce normal voltage at the receiving end. The charging kilovolt-amperes was approximately 75,000 which was quite close to the calculated value for lines and transformers.

This was the first full-speed operation of the unit, and a generator bearing began to run hot, so it was necessary to run at reduced speed and voltage from 3 p.m. until required to bring conditions back to normal in advance of striking the large arc at 7:41 p.m.

Other than the difficulty with the generator bearing, no other trouble was experienced in this first test and use of the complete line.

## Further Installation and Test Work

During the following two weeks the relay and carrier telephone installation work was completed and initial adjustments made. Changes in the generator bearing to increase the flow of oil, overspeed tests, and installation and initial adjustments of the generator and transformer differential relay system and other auxiliaries were made. The installation of carrier-current supervisory-control system was under way, but was not completed until a later date.

During the relay installation, the line was charged on several instances for adjustment of potential devices used in connection with the relay system. No difficulties were encountered. It was anticipated that further test and observation and adjustment of the relay system would have to be made during operation. Final adjustments of the telephone system could best be made with the line in operation, so that suitable adjustments of input with respect to the noise level could be made.

## Commercial Operation

Actual use of the line for regular power service began at 7:05 a.m., October 22, 1936, using the south circuit and one generator. Low head in the reservoir limited the generator output to approximately 50,000 kw at full gate. With loads as low as this, it was possible to take the line out of service between midnight and morning whenever desired for adjustment or installation of auxiliary equipment. At the switching stations such work involved permanent installation and adjustment of relay equipment and carrier-current telephone equipment.

Adjustment of pallet switches and other small elements of control were made. The installation work pertained principally to the supervisory control equipment. The line patrolmen took advantage of such opportunities to take out line sections to replace some insulator units slightly damaged by bullets or in course of construction work, and make any other corrections to hardware revealed as necessary by the careful inspection which was being made.

The second generator, unit *N*-4, became available December 28. Both units were put into service immediately at full output with the available head. The bringing in of these units at this time was particularly important in avoiding delay in the program of frequency changing under way. The Boulder Dam system was depended on, and used as a fully dependable system during this exacting time, when keeping adequate reserve for two frequencies was a major problem.

It may be said that these early months of operation constituted the test period for all of this relay, supervisory control, and communication equipment. Observations and tests have been continued to serve as a guide in the proper adjustment of the carrier current equipment and point the way to minor changes of design that may be necessary in any of the elements of the equipment, to meet the requirements, set by the Department, to operate under certain defined unusual circumstances.

By the end of the year 1936 the frequency-change work had been essentially completed, and the system was proceeding on a normal basis. The fourth generator became available March 18, 1937. In general the plant has been loaded up to the limitations imposed by low head until after the runoff of 1937. Since then, the maximum load has been essentially limited by the defined rated operating capacity of the transmission system. Since the Department acquired the system of the Los Angeles Gas and Electric Corporation on February 1, 1937, it became desirable from the standpoint of economy to load the Boulder system as much as possible and use the acquired steam plants for standby. The rapid growth of load on the Boulder system is indicated in table I, showing the kilowatt-hours per month supplied to the low-voltage side of the step-up transformers, the monthly peak output of the main generators in kilowatts, and load factor. In addition the average monthly efficiency of transmission is given. This figure includes losses in the step-up transformers, line, autotransformers, and synchronous condensers. One other transformation from 132 kv to the 33-kv load bus is not included.

During this period of operation, the personnel have had to acquaint themselves; with new types of intricate control equipment, a large and complicated generating plant, a new line arrangement at switching stations, and a line of unusual characteristics and length, and continue operation while extensive installation and test work was going on with such equipment. Under the conditions it is remarkable and the operating group are to be commended on the fact, that a large number of interruptions did not occur from the human element. The operation of the line has been exceedingly reliable and satisfactory. There was a period of ten months operation absolutely free from interruption due to any cause.

Of the five interruptions that have occurred, four have involved the human element as well as the control equipment, so that it cannot be stated beyond all doubt wherein the failure occurred. Such interruptions occurred during operating procedure. The other interruption was caused by a flood undermining a tower and causing relay action which took place correctly. A brief description of each of these cases will be given.

## Interruptions

The first interruption was of very minor importance and occurred at 6:21 a.m., December 15, 1936, during the process of putting the north line back in service after being out on a clearance. The north line was energized for the complete length and had been placed in parallel at Silver Lake and at Boulder. While closing the parallel at Victorville, some faulty action of undetermined origin caused the south line to relay open and interrupt service. The line was carrying 50,000 kw.

The second interruption occurred at 9:11 p.m., January 6, 1937, when the line was delivering 130,000 kw. Sleet had been reported as forming on the conductors at Mountain Pass between Boulder and the Silver Lake switching station. The patrol road was becoming impassable, so it was decided to alternate the load on the north and south line sections between these stations. As will be indicated in the paper on relaying, transients during switching operations had been such as sometimes cause relay action to occur on the incoming line. The north line section had been energized from Boulder and in the process of placing it in parallel with the south line it relayed. Then either the supervisory control indication did not come in correctly, or the Boulder operator did not notice, or else did not wait long enough for the supervisory signal to come in before tripping the south line and interrupting service. Due to the line being charged from the receiving end high voltage existed for one or two seconds until the operator opened the lines so Boulder could get the transmission line ready for resynchronizing.

The third case of interruption did not occur for nearly a year and happened at 10:25 a.m., November 8, 1937, while the relay maintenance crew were making their routine tests on the performance of the relay equipment. In clearing the balanced line, to put them back in serv-

Table I

| Year | Month | Energy to Step-up Transformers (Millions of Kilowatt-Hours) | Generator Peak Kilowatts | Load Factor (Per Cent) | Efficiency of Transmission (Per Cent) |
|---|---|---|---|---|---|
| 1936 | October* | 6.20 | 55,000 | 48.0 | 86.9 |
| | November | 46.70 | 108,000 | 60.1 | 90.4 |
| | December | 67.20 | 162,000 | 55.8 | 91.3 |
| 1937 | January | 80.50 | 156,000 | 69.4 | 93.3 |
| | February | 71.50 | 152,000 | 70.1 | 92.5 |
| | March | 74.20 | 153,000 | 65.3 | 92.0 |
| | April | 76.40 | 171,000 | 62.1 | 92.3 |
| | May | 76.60 | 167,000 | 61.7 | 94.7 |
| | June | 79.30 | 182,000 | 60.5 | 95.0 |
| | July | 81.60 | 166,000 | 66.1 | 94.9 |
| | August | 85.60 | 216,000 | 53.3 | 94.1 |
| | September | 99.00 | 250,000 | 55.0 | 93.1 |
| | October | 119.10 | 276,000 | 58.0 | 93.6 |
| | November | 117.70 | 277,000 | 59.0 | 93.8 |
| | December | 123.33 | 277,000 | 59.9 | 93.7 |
| 1938 | January | 120.40 | 281,000 | 57.7 | 93.8 |
| | February | 116.60 | 273,000 | 63.5 | 93.8 |
| | March | 111.97 | 267,000 | 56.4 | 93.6 |
| | April | 111.06 | | | 93.8 |

* 235 hours.

ice, some jumpers were inadvertently left so as to involve a complication of several circuits on a relay test panel, in such a way as to have the effect of connecting the secondary of the potential transformer through the residual current coil of the carrier pilot relays. Also due to the short circuit on the potential transformer, voltage on the directional element was such as to cause the relays to indicate a fault on both lines. When the relay test switch was turned to put the relays in operation both lines were tripped.

At the time of this interruption Boulder power plant was carrying 217,000 kw. It is estimated that the maximum receiving-end voltage of the lines was approximately 385 kv at 4.5 seconds after the interruption and that the maximum frequency was 65 cycles per second

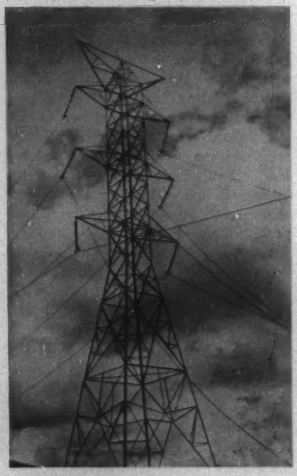

**Figure 2. First tower east of washed-out tower**

5 seconds after the lines opened. Such values are not considered excessive for dropping this much load. These conditions caused no flashovers of line insulation nor difficulty in the autotransformers connected to the lines.

The fourth interruption occurred at 6:56 p.m., March 2, 1938, as a result of the undermining of a double-circuit tower by the worst flood of 50 years record in the Los Angeles area. The actual failure began several minutes earlier. At 6:50 p.m., the north circuit relayed out, by balanced line relays, due to a single-phase-to-ground fault on the *A* phase (top conductor). Since the overhead ground wire broke free from the tower on this side, it is believed that this first relay action was caused by the ground wire sagging down on the conductor below. The complete relay and circuit-breaker action required only 3.5 cycles or 0.06 seconds. This is as designed and the circuit-breaker action was without distress. Boulder was carrying 170,000 kw at the time of fault. System voltage drop was scarcely noticeable, and very small power swing took place, the maximum at Boulder being 177,000 kw. Since the operator knew what was taking place, load was then reduced on the Boulder circuit.

Six minutes later the tower completed its process of falling and the bottom conductor of the south line (also *A* phase) contacted ground and was relayed by carrier pilot relays, in $5^1/_2$ cycles at the receiving end and $10^1/_2$ cycles at the Victorville end. The load being carried was 130,000 kw.

This second fault was less severe than the previous one, as very considerable less ground current flowed indicating considerable resistance at the point of fault. The relay time was compatible with the ground currents involved.

The generators speeded up to about 63 cycles 4.6 seconds after the fault. The sending-end voltage did not rise appreciably.

The last interruption occurred at 10:16 a.m., March 29, 1938. It was an illustration of what can happen due to complexity of circuits in a modern power house, where doing some simple but unusual operation brings into action other equipment, possibly out of mind at the time. In this case, while gathering nameplate data for inventory purposes, the circuit breakers for supplying d-c control power over two feeders, were being alternately taken out of service. In this process, the second breaker was opened before the first was closed, removing the control power. Then all normally energized control relays dropped out, establishing a condition which energized the governor shut-down solenoids when the bus was re-energized. This caused all turbine gates to move to the full closed position, where all but one unit latched shut. On this one unit the gates came back to the full open position, but as all of its output was used up in driving the other units and churning water, no power reached Los Angeles, and the Boulder circuits were opened by hand to permit Boulder to clear up its trouble and get the line ready for synchronizing. The load on the machines at Boulder at the time was 230,000 kw.

The Boulder speed dropped to 45 cycles about 30 seconds after separation. The regulators were set to maintain 17,000 volts at the generator. The units were then put on hand control, and gates opened to bring the speed up. Due to no load, they came up more rapidly in speed than the regulator could adjust voltage, considering the heavy field current and the effects of line-charging current with increasing speeds. The leading current also acted on the cross compensation of the voltage regulators, causing them to regulate seven per cent higher than their setting. The maximum voltage at Boulder was approximately 385 kv. The receiving-end voltage was not appreciably different because of the very large lagging exciting current taken by the autotransformers at the receiving end, with high voltage.

## Electrical Loading and Performance

Due to the continuous use that has been made of this line there has never been opportunity to conduct any program of accurate testing to determine the line characteristics. However, with open-circuit conditions and normal voltage at the receiving end, switchboard readings were taken of current and voltage on the high-voltage side at Boulder. A comparison of these results with values determined by transmission system constants calculated with slide rule, for the same complete circuit, revealed that the calculated sending-end voltage was 238,000 while the test average was 239,000 and the calculated current was 200 amperes while the test average was 194. Such constants were determined on the simple isolated circuit basis, without refinements including ground wire effects, or height above the ground, etc. This is sufficient check to give assurance that the circuit is operating about as anticipated. The general performance under load is also as expected from calculation of performance.

In the design work, the assumption was made that the generator terminal voltage would in general be held constant at the normal value, with a fixed setting of the voltage regulator. In actual operation a slightly different policy has been followed to date. The regulator setting is changed with the load, ranging from 90 per cent voltage at very light loads up to 105 per cent at the higher loads. This gives operation in accordance with the criterion for minimum line loss, and also permits the synchronous condensers to operate at lower outputs.

The high efficiency of the line is indicated in table I.

Operation of the line has as yet developed no conditions which provide a full check on the stability limit. However, some verification of design can be obtained from the clearing of the first circuit. During the trouble of March 2, 1938, when a tower was taken out by flood at a time when the load was 170,000 kw, the relay and circuit-breaker action was so prompt that only a single-phase-to-ground fault resulted. However had slower circuit breakers been used the fault would presumably have had time to develop into a two-phase-to-ground or three-phase fault. This proved to be the case when a very similar tower failure took place on the Department's 110-kv double-circuit line, where an *A*-phase-to-ground fault developed into a two-phase-to-ground fault within 3 cycles and in 13 additional cycles became a three-phase fault. For a three-phase fault at this load the more permissible duration of fault to avoid instability is of the order of one-third second. If the customary speeds of fault removal, such as 20 to 30 cycles had been used, this fault would probably have produced instability. As it happened, there was hardly an observable flicker of voltage and hardly any power swinging. Operation was perfect until six minutes later when the tower had fallen so as to involve the second circuit.

## Mechanical Characteristics and Loading

### Conductor

All of the line carried on single-circuit towers is designed to carry one-half inch of radial ice loading with a wind loading of eight pounds per square foot of projected area, with a safety factor of $2^1/_2$ on the ultimate strength. The nearest approach the line will probably have to these loadings occurred during the winter of 1936–37.

The first evidence of sleet formation on the line occurred during December 1936 when a few spans at the top of Cajon Pass were observed to have one-half to three-fourths inch of ice measured radially in the vertical plane, but having very little thickness on the sides. At this time the wind had a velocity of approximately 30 miles per hour. Similar conditions existed at another mountain pass between Boulder and Silver Lake stations. The conductor completely recovered to its original normal sag after the loading was removed.

The sleet formation in Cajon Pass was watched with considerable interest as an effort was made in locating the line to choose proper elevations, and the appropriate slope of the mountains, so that sleet difficulties would be minimized. The experience of some other lines in this area had been that sleet and snow has formed up to diameters in excess of eight or ten inches and broken down conductors and structures. In the storm under discussion some lines had such difficulties. It is now believed that the route selected is probably a good choice.

During the period of construction and operation, several periods of relatively high wind velocity, probably up to approximately 50 miles per hour, have been experienced without giving any trouble. This is considerably below velocities that would give mechanical trouble. The design of clearances is based on a wind velocity of 70 miles per hour without ice so there was no real danger of flashover at lower velocities.

During the year beginning September 1935, while construction work was in progress a survey of line vibration was carried on, in which 71 locations likely to be favorable to producing conductor vibration were investigated, by using a recorder employing an inertia arm. If any appreciable vibration was indicated by this instrument, a smoked-chart recorder was put in place to measure amplitude. Such were installed in 44 of the above locations.

Approximately 18 miles in scattered locations or seven per cent of the total line, gave evidence of vibration in excess of one-half inch double amplitude at a point six feet out from the clamp, and in excess of one per cent of the time during which wind was favorable for vibration. In only one case was this amplitude maintained for as long as five per cent of the time that the wind was favorable for vibration. At this same location the amplitude reached the maximum of any place on the line, which was only $1^1/_8$ inches, double amplitude. This highest amplitude only prevailed for 0.01 per cent of the time that wind was favorable for vibration.

Figure 3. Towers west of washed-out tower

Based on the recorded data, none of the locations had vibration of sufficient extent to lead to fatigue failure within a 50-year period. This knowledge is based on fatigue studies on the conductor used. However, in order to be conservative and make allowances for differences that might exist due to the relatively short time of survey at each location, it was decided to equip the 18 miles mentioned above with dampers.

The studies by the Department have served to indicate that theconductor being used has a high degree of self-damping, and is entirely satisfactory in its performance in resisting fatigue failure.

### Hardware

The free-center-type of suspension clamp used on this line has operated very successfully. Although the cable lies in pivoted saddles without clamping, there has been no creep. The knife-edge pivots used have shown no wear where examined, and no wear was indicated for a clamp carrying normal load in a vibration fatigue test on the cable. During the recent tower failure due to the flood, the center wedge grip engaged the body of the clamp and held dead end strains on the cable as anticipated.

The wedge-grip strain clamps and conductor connectors have proved entirely satisfactory. One refinement however was necessary and became evident at the start of the stringing operations. Conductor stringing was started with one crew in the Kingston Valley section of the line on March 15, 1935, and this was followed by a crew in the Silver Lake section on March 21, 1935. The first span of cable erected at Silver Lake pulled out of the dead-end fittings during the erection process, and this was followed by a

similar occurrence at Kingston a few days later. We had previously broken, in laboratory tension tests, several hundred pieces of this cable when dead-ended in these same fittings and in every case the dead-end fittings functioned perfectly. However, the cause of the trouble was found to be in the design of the inner wedge or chuck of the dead-end fittings. The chuck was not flexible enough to accommodate certain combinations of manufacturing dimensional tolerances of cable and dead-end fittings. All chucks were additionally slotted to make them more flexible and no additional trouble was experienced.

In connection with the discussion of hardware it is of interest to call attention to a special unforeseen condition that exists along about seven miles of line. At this point the line is proceeding in a westerly direction after going through Cajon Pass. Here the line is running in the foothills parallel to the axis of the mountains, but there are frequent small canyons at right angles to the direction of the line. The prevailing winds, which are frequent and of moderately high velocity, are from the north and flow down these little canyons with varying velocity in adjacent canyons. The result is that adjacent spans of the line have unequal and continually shifting wind loading, which produces considerable longitudinal motion as well as the normally anticipated transverse swing of the insulator strings.

Due to this action, the commonly used bent-rod type of hanger bracket, which has a hooked end carried by holes in clip angles attached to the cross arms, is causing some wear at the points of support. An improved type of hanger, devised so as to give rolling action rather than sliding action, is being designed for use at this location. For the remainder of the line this hanger has given no such difficulty.

It was also observed with this type of hanger, that in comparison with structural-steel or plate type of hangers, that there was more tendency for the clevis pins to move endways and eventually bring the cotter key against the clevis where it could wear. The exact cause of the action is not known, but may be due to the large eye and the curved surface on which the pin rests, coupled with the larger motion with the wind that comes with the use of the hollow conductor of light weight. To eliminate any worry of failure due to this cause the pins were replaced with bolts and slotted nuts with cotter key to lock the nut.

The seven-mile section here referred to had the same type of longitudinal motion take place on the overhead ground wire, causing the clamp to swing 45 degrees. The result was excess wear on the trunnion pivots of the suspension clamps at such locations. At the present time, designs are being made for special clamps,

**Figure 4. Tower after two footings were lowered five feet by washout**

to withstand this kind of action. This type of wear is not found elsewhere on the line.

The special ground-wire strain clamp designed for this line has been satisfactory throughout the line.

### Towers and Footings

The satisfactory design of the towers and footings can best be indicated by a discussion of how these structures withstood the flood conditions that prevailed on March 2, 1938. Although one tower was lost, as has been indicated, there were many more at other locations that were in jeopardy and which with less liberal design, especially of footings, would have failed.

Floods in this area involve many short streams, normally carrying little or no water, which originate in the mountains, come down steep canyons, and in the case of the larger streams carry probably 50,000 cubic feet per second. The velocities even through the coastal plain are exceedingly high and very destructive. This flood was the worst in over 50 years. It was exceedingly widespread in its damage, affecting disastrously a large number of power lines, communication lines, railroads, highways, pipe lines, bridges, and many other important structures.

The tower that was undermined was in the wash area, but to one side of the established channel. The destructive power of the water can be judged from figure 1 showing a picture of the one remaining footing, with the tower visible approximately 200 feet downstream where it was carried by the force of the water. Obviously a failure of this kind put tremendous strains on the conductors and the adjacent suspension towers. In this failure the north ground-wire clamp broke free from the tower and the bottom conductor on the north side broke free at the bottom insulator. The other conductors were broken, by the pulls imposed by the falling tower.

The tower shown in figure 2, is immediately to the east of the tower that went out and shows that all arms and insulators remained intact. The insulators have a strength just under the broken wire pull that the cross arms can withstand. This tower received some help from a dead-end tower just beyond. On the west end, however, all the towers were suspension towers. The resulting strains on the conductor were such as to break insulator strings from one to three towers back depending on the conditions of pull. This is shown in figure 3. The towers were not damaged although they had to meet a duty approaching that on a strain tower. They are designed to withstand one broken conductor and one broken ground wire under maximum ice and wind conditions.

At another point in a rather indistinct water channel, a tower had all four footings completely exposed, and remained standing, due to the dead weight of the concrete footings. In another case, an angle tower, which was a considerable distance back from a water channel, had two of its footings undermined by the progressive cutting back of the bank. This tower is shown in figure 4. The footings were lowered about five feet but the weight of the footings prevented the tower from being pulled over by the transverse pull due to the angle.

These cases are representative of several others, where the sturdiness of the towers and the weight of the footings served to limit our outage to one location on the Boulder lines.

However, although this flood with its previously referred to widespread damage, did create a few points of danger and the actual loss of one tower, nevertheless to a very large degree the correctness of the location of the line and the placing of the structures is verified by the

# Symposium on Operation of the Boulder Dam Transmission Line—Corona Experience on Transmission Line

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THE original basis for the selection of 1.4 inches as the diameter of the conductor for the Boulder Dam transmission line was provided principally by test data taken at the Ryan High Voltage Laboratory, at Stanford University, by the Department of Water and Power in cooperation with Doctor Joseph S. Carroll, on conductors ranging from 1.125 inches to 2 inches in diameter.[1] Also reference was made to other previous corona work at the same place.[2,3,4] An analysis and use of the data,[5,6] taking into account temperature and altitude effect and making some allowance for unknown factors affecting corona laws that had appeared in many of the tests, led to the final recommendation of 1.4 inches as the diameter for the conductor for 287.5 kv.

Cost curves for the line in terms of conductor diameter indicated that in the vicinity of minimum cost the curves were exceedingly flat, with about one per cent change from the minimum cost representing a diameter difference of 0.1 inch. Due to the peculiar shape of the corona loss curve, such economic choices would occur at the knee of the curve. However, the test work at Stanford had revealed that there were variations in corona loss that could not be accounted for by known temperature or barometric variations or other partially known factors such as humidity or surface conditions. The general indication was that after stable surface conditions had developed such factors would not cause a shift in the loss curve of more than ten per cent in voltage for the same loss. Realizing that if a conductor was operating near the knee of the curve and that this much shift in the loss curve of the conductor might run the losses tremendously and uneconomically high, it was decided to be somewhat liberal in selecting the conductor diameter. The excess diameter over that apparently required was taken as approximately 0.1 inch.

Tests on 1.65-inch-diameter hollow copper conductor of the segmental type, referred to as type *HH*, had indicated somewhat lower losses for that form of cable as compared with what would be expected from conductors with a stranded surface. It was believed, however, that a stranded cable of the diameter selected would be satisfactory for use on the line. Due to the small knowledge at the time on this subject of surface contour, no distinction was made for the difference in corona loss for these cables, in preparing specifications.

Later tests on various 1.4-inch-diameter cables, which were submitted by manufacturers in response to specifications, demonstrated the lower losses to be obtained with the smooth surface segmental type,[7] which was the conductor used on the line. This conductor also had economic advantage in that it could be made with the exact amount of copper necessary to carry the mechanical and electrical loading involved.

From the corona standpoint, the tests on 1.4-inch-diameter conductors indicated that any of them should be satisfactory, and that the 1.4-inch-diameter segmental-type conductor would be liberal as the losses were quite small, providing the surface conditions existing in the laboratory tests would be maintained in the field, by care in erection.

In addition to selecting a conductor size that would give low corona losses, a special effort was also made to design line hardware so as practically to eliminate unshielded corners or small radii that would be conducive to the formation of corona. The suspension clamp is essentially a box-shaped shell of smooth exterior with very liberal radii of curvature for all edges and corners. The strain clamps and connectors are designed so as to have rounded edges and dimensions that will make them corona free. In addition the use of $1^1/_4$-inch pipe for arcing horn structures at the high voltage end of insulator strings gives adequate shielding to hardware parts and the lower insulators to avoid corona formation at such points, as well as eliminating corona from the horn itself. In addition the long insulator strings used further reduced the duty on insulators to a point where corona formation at the insulators is practically eliminated unless disturbed by dirt and fog or other contamination.

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1. For all numbered references, see list at end of paper.

## Noise Observations

### Dry Weather Corona

After a line is in operation, a great deal of the judgment, concerning the performance of conductors with respect to corona, must be based on noise observation. This comes from the fact that, in a long line with low corona losses, it is very difficult to make any test arrangement whereby corona losses can be accurately determined. Such work involves not only the problems of accurate measurement of power at low power factor and high voltage, but involves subtraction of copper losses, affected by temperature and altitude, from the total losses, and the remainder is the corona loss. Such a procedure is subject to large errors. Hence, the noise observation is the most practical method of determining the relative corona performance of conductors.

Noise observations were made on the line during dry weather, and the noise was found to be very low. Under the worst conditions, the noise was audible only at a distance of a few feet from the conductor. Under average conditions, the noise was inaudible at a distance of 50 feet from the conductor. The noise was found to be independent of the conductor size, and was attributed to the surface roughness of the conductor.

### Wet Weather Corona

Wet weather corona was found to be much more audible than dry weather corona. The noise was found to be dependent on the conductor size, and was attributed to the surface roughness of the conductor. The noise was found to be independent of the conductor size, and was attributed to the surface roughness of the conductor.

## Conclusion

The performance of other elements of the system will be discussed in appropriate papers associated in this symposium.

In conclusion it can be stated that the performance of the transmission line and its associated equipment has been satisfactory. The few difficulties that have been discussed are not to be regarded as materially detracting from the success of the line as a whole, but are mentioned so that the electrical industry might profit from a knowledge of their existence.

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## Discussion

For discussion see page 156.

**Figure 1. The test line and high-voltage wattmeter arrangements for Victorville corona tests**

The steel towers in the background are part of the main transmission lines

perature at various points and the variation in the charging current along the line. In order to maintain proper voltages at each end of the line, in accordance with those existing during normal operation, synchronous condenser operation is necessary and determination of such losses must also be made. The interpretation of the results is also difficult due to the variation in elevation and temperature along the line.

When 90 miles of the line was first energized from the Los Angeles end, observations taken near the receiving station indicated a corona noise of moderate intensity that could be heard for a distance of approximately 400 feet. This statement means that such noise is at the threshold of hearing at that distance when observed by a person accustomed to listening to corona noise and who is concentrating his attention on its observation. Newly energized circuits generally have a higher noise level than found on the same circuit after weathering. After this conductor had weathered for the month or so until normal operation was in effect, and then further weathered for about two months with voltage applied, the noise as observed for dry weather was very much reduced and became essentially inaudible when observed from the ground when standing directly under the line midspan. In general, in the vicinity of Los Angeles, it is only under exceptional conditions that the dry weather corona noise becomes audible when so observed. Under such conditions noise can develop very suddenly and apparently with no observable change in temperature or humidity or known factors affecting corona loss. It would be of an intensity that becomes inaudible at about 200 feet, and is not of long duration and is less noisy than tire noise from an automobile traveling on smooth pavement.

In the foothill region east of Los Angeles where the line is at elevations of approximately 2,000 feet, the dry-weather noise is not much different from that which has been discussed. It can probably best be described by saying that an occasional corona brush manifests itself with an intermittent buzzing sound.

When observations are made in the mountains and desert, inconsistencies begin to appear. The highest noise levels are not found at the high elevations as would naturally be expected from the variation of the air density factor. Observations at elevations in excess of 4,500 feet are usually inaudible if the location is such that the observer cannot be close to the midspan because of a gulley or canyon. The audibility at the tower due to approximately 100 feet elevation of the conductor is quite low. At other points of high elevation where the contour of the ground permits observation at closer distances, a mild corona noise is heard.

One of the few sections producing the most noise is in the vicinity of mile 175 from Boulder at an elevation of 3,200 feet. When at its highest level the noise at this point has the crackling sound associated with a small grass fire and also a low humming sound similar in quality to transformer hum, is sometimes heard. When the noise is at its maximum, at this location, it becomes inaudible at a distance of 1,200 to 1,500 feet. This noisy location exists for a distance of about three miles on both circuits. There is considerable variation in the noise from day to day, over and above that due to temperature changes. A high degree of noise has been observed on cool evenings and very quiet operation has been observed during warmer daytime periods, which is contrary to normal expectations. Sometimes in the course of a few minutes a conductor will exhibit alternations of noise and quietness.

At night, no uniform envelope of corona is visible, as the discharge is in the form of scattered and intermittent brushes from two to eight feet apart, which are visible at midspan where the conductor is about 30 feet above the ground.

There has been occasion to notice about four other similar areas where such corona conditions exist but probably to a lesser degree.

During wind storms, in the desert, other lower voltage lines had been observed to have a glow similar to corona, probably due to charging or discharging dust particles or other atmospheric charge phenomena. On the assumption that atmospheric charges might have some influence on corona loss and noise, an observation station was set up in the vicinity of mile 175. At two locations, about 800 feet and $1^1/_2$ miles from the line, antennas about 50 feet long were carried on masts 30 to 40 feet above the ground on hilltop locations. An electroscope was used to measure the potential of the antennas to ground. Arrangements were also made adjacent to the line to measure radio interference noise, and to record audible corona. By taking observations simultaneously at both places, it was thought it might be possible to obtain some correlation between atmospheric charges and corona noise. Voltages up to approximately 2,000 volts were measured by means of the electroscope, which is not uncommon for antennas in the desert. Very little if any correlation was observed between the accumulation of charges on the antennas and noise on the transmission line.

For the great part of the line length, corona noise is at a comparatively low level. At elevations of the order of 2,300 to 2,700 feet, which is about the average elevation of the line, and on a normal dry day with the temperature a little above average, the noise is at the threshold of audibility at a point midway

between the two single circuits, which have a separation of 265 feet. This general low level of corona noise is very satisfactory and indicates that the conductor design has been adequate.

### Wet Weather Corona

As soon as rain begins to fall on the conductor, corona noise becomes evident at any location. The noise is so directly coincident with the beginning of the falling of the drops, that the cause of the loss and noise is either the exchange of charges between drops and the conductor or the mechanical pattern and shape of conducting water caused by the rain drops striking the conductor. The motion of the drops in the alternating electrostatic field may also contribute to the humming sound quite evident during rain. The resulting noise is moderate.

At an elevation of 1,000 feet, where adequate darkness prevails, it is just barely possible to see rather intermittently the bluish corona glow during rain. At elevations in excess of 2,000 or 2,500 feet, and similar darkness, the faint blue glow of corona is visible for about two spans. The glow frequently has an intermittency that gives the effect of longitudinal motion along the conductor. It is believed that this effect may be due to rain drops hanging along the bottom of the conductor, when it is vibrating slightly. Then the drops are either shaken loose or elongated by the motion, which develops glow either by changing the gradient, or by carrying small charging currents to the falling drops.

## Desert Loss Measurements

For the past several months consideration has been given to the design of a third 287.5-kv Boulder circuit. Due to the fact that no high-voltage source was easily available for testing in the actual line location heretofore, the work had all been done at the Ryan laboratory. On the basis of such tests, 1.4-inch-diameter stranded conductor was considered to be satisfactory for 287.5-kv operation and 1.4-inch-diameter hollow copper conductor of the segmental type showed appreciable liberality. These facts together with a general excellence of performance of the 1.4-inch conductor being used, brought about the suggestion that the possibility of using a smaller diameter of conductor be investigated. However, observations of noise at some special locations on the desert, as previously mentioned, indicated some departure from the laboratory conditions and made it desirable to have some loss tests made actually under desert operating conditions.

Since high voltage was now available from the Boulder circuit, a test set up could be made at the Victorville switching station. By isolating the portion of one circuit from Boulder to Victorville and supplying it from one generator, voltage could be controlled from any desired low value up to about 360,000 volts at Victorville. High-voltage wattmeter equipment similar to that used for some of the tests at the Ryan laboratory,[8] and a suitable test line, were erected. General views of these test arrangements and their location with respect to the switching station are given in figure 1 and figure 2.

**Figure 2. High-voltage wattmeter equipment for the Victorville corona tests**

The steel structure in the background is the Victorville switching station

At this location, tests are in progress on 1.25-inch-diameter and 1.4-inch-diameter hollow copper type *HH* conductor and also on some 1.4-inch stranded aluminum conductor steel reinforced that had been tested previously at the Ryan laboratory. At the conclusion of this work, the details will be reported.

One important result of these tests was that, after due allowances had been made for barometric pressure and temperature, it was found that the losses at Victorville were appreciably higher than those obtained at the Ryan laboratory. This is true for all conductors tested to date, including stranded as well as those of the segmental type. The aluminum cable is the identical sample tested at Stanford and its surface was carefully protected so as not to be roughened or damaged in shipment or erection. The 1.4-inch type *HH* cable was a fair sample of that cable, not noticeably different to any that had been heretofore tested or used on the line. The 1.25-inch diameter type *HH* cable was a new size manufactured for the test, but the equivalent of its losses at Stanford can be judged from interpolations made from tests on 1.1-inch and 1.4-inch-diameter cable.

The increased corona losses measured at the Victorville test location are sufficiently higher than those obtained at the Ryan laboratory, so that the difference cannot be explained on the basis of any reasonable altitude and temperature corrections. The losses are also sufficiently high so as to make unattractive the use of 1.25-inch-diameter hollow copper conductor of the segmental type or even 1.4-inch-diameter conductors with a stranded cable surface. As far as can be judged by measurements to date, which are not fully completed, 1.4-inch-diameter hollow conductor of the segmental type as used on the line will have losses sufficiently low as to confirm the design and size of this conductor as being satisfactory for 287.5-kv lines.

Such higher losses have been found on clear days and under such conditions that wind, humidity, temperature, and barometric pressure do not offer sufficient explanation for the results. The conductors have been tested as soon after washing as was possible, without demonstrating that the accumulated contamination of the conductors was increasing the losses. Among the intangible items that have been mentioned as possible causes are such things as atmospheric charges, sun-spot phenomena, invisible charged dust particles, the presence of radioactive materials in the vicinity or as dust on the conductor, or the presence on the conductor of any

# Symposium on Operation of the Boulder Dam Transmission Line—Insulation and Lightning Protection

By BRADLEY COZZENS
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**Synopsis:** This paper covers a résumé of the fundamental principles of insulation and lightning design for the Boulder Dam transmission line, including the fog problems encountered in the coastal regions and the lightning problems of the desert section. The operation in both areas is covered, with particular reference to the lightning encountered during two years of construction and one year of operation. A description of the lightning recording equipment with current values and frequency of strokes is reported. From these values the adequacy of the design is definitely indicated.

THE Boulder Dam-Los Angeles transmission system of the Bureau of Power and Light traverses country presenting a wide variation in geological and climatological conditions. Starting from practically sea-level conditions at the Los Angeles terminus, the line passes through low-lying alluvial valleys, with their accompanying fogs, through the foothill sections and across the gravelly and rocky talus slopes at the base of the San Gabriel Mountains. Passing over Cajon Pass at an elevation of 4,415 feet, the line drops gradually into the Mojave Desert area for the remainder of the 190 miles to the Boulder power plant. For those unfamiliar with this territory, it is a mingling of mountain ranges, large sloping valleys of a generally rocky character with occasional sinks or dry lakes that are flooded at two- to four-year intervals by desert storms. In this section the line varies in elevation from 800 to 4,862 feet with the general trend being between 2,000 and 3,000 feet. The average rainfall in this territory is between one and six inches per year which usually comes in one or two storms of cloudburst proportions.

In the area between the Cajon Pass and the coast the line is subject to long dry periods during the summer months, at which time the insulators collect considerable dust aggravated by field cultivation. This period is followed by the heavy fogs, in the fall of the year, which fogs come without much warning and seriously impair the effectiveness of any insulation. Although in the desert area there is appreciable dust, there is almost complete freedom from fogs and its attendant problems. The rains come as heavy downpours that serve primarily to wash insulation rather than producing any insulation problem from this standpoint.

The familiar isokeraunic charts presented by the United States Weather Bureau[1] show Los Angeles having less than 5 lightning storm days per year; the mountainous section between Los Angeles and the desert, approximately 7; with the frequency gradually increasing to approximately 30 in the vicinity of Boulder Dam. Prior to the design of the line, these values were partially substantiated by a survey of the territory and of the operating records of the few transmission and telephone lines that traverse it.

Thus two definite insulation problems were presented; namely, insulation for the lightning voltages of the desert and insulation to be free from flashover due to dust and the fogs of the coastal region. Since the system was to be a major source of supply for the City of Los Angeles, justifying the high degree of reliability specified by the management, the design contemplated practical immunity from flashover from either lightning or insulator contamination and fog.

## Fog Design

Insulation that will withstand contamination and wetting of fog has been a baffling problem on the Pacific Coast for many years. Studies made in connection with the design of the Boulder Dam line and other lines of the Department gave a good understanding of the action of insulators under these conditions and also led to the redesign of lightning arresters[2] to operate under such conditions. Under fog conditions the leakage current over insulators is 20 to 200 times the normal capacitance current. The voltage distribution is thus determined by surface resistance alone.

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1. For all numbered references, see list at end of paper.

chemicals that may increase the emission of electrons. A new field of corona investigation is thus opened up.

As a final check on corona loss on the Boulder transmission line, reference should be made to the over-all monthly efficiencies that are given in table I, of the companion paper on general operation of the transmission lines. These losses agree so closely with calculated resistance and equipment losses, that the corona loss is negligible.

## Conclusion

The experience obtained to date in the operation of the line indicates a general low level of audible corona noise and conservative corona losses thus substantiating the original design.

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## Discussion

For discussion see page 156.

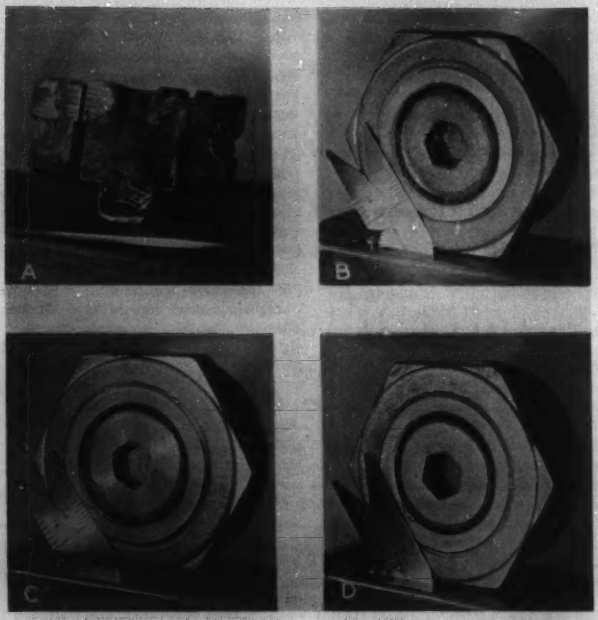



**Figure 1. Gaps used to fasten counterpoise to tower leg and to break the electrolytic circuit between copper counterpoise wire and zinc-steel tower legs**

*A*—Section through gap, stud cut off
*B*—Gap flashed by natural lightning
*C*—Gap flashed in laboratory, 75,000 amperes
*D*—Gap flashed by natural lightning

its use in populated areas. However, this unit has approximately 20 per cent lower impulse flashover than the conventional-type insulators which eliminated its use in other locations. Little, if any, improvement was found for any of the so-called fog-type insulators available for these tests. To facilitate cleaning and yet obtain the greatest leakage in a given string length, the ten-inch-diameter five-inch-spaced standard suspension disk was selected for this type of service. In accordance with tests and the successful operation of 20 such units on 220 kv in northern California it was felt that the use of 24 units at the higher voltage but somewhat less severe fog condition on the Boulder Dam lines would preclude the possibility of flashover for a number of years. To prevent disturbance in the residential section through which the line passes a program of washing the insulators once or twice a year

Since the drying of the surface film increases its resistance and consequently the voltage duty and power dissipated in the dry areas, these drier sections will continue to heat and dry carrying more voltage duty while the other areas become wetter and take less and less voltage duty. The caps of these drier units may operate in excess of 35 degrees Fahrenheit above the ambient air temperature, while the high-resistance area adjacent to the pin may be much hotter.

The results of the fog tests on practically all commercial and many special insulator shapes showed the old-type 12-inch flat disk to have the lowest leakage current and ability to insulate in fog. Though the smooth surface and poor electrostatic stress distribution of this type unit inhibits dust deposition, the same conditions exaggerate the sparking and arcing of the wet units eliminating

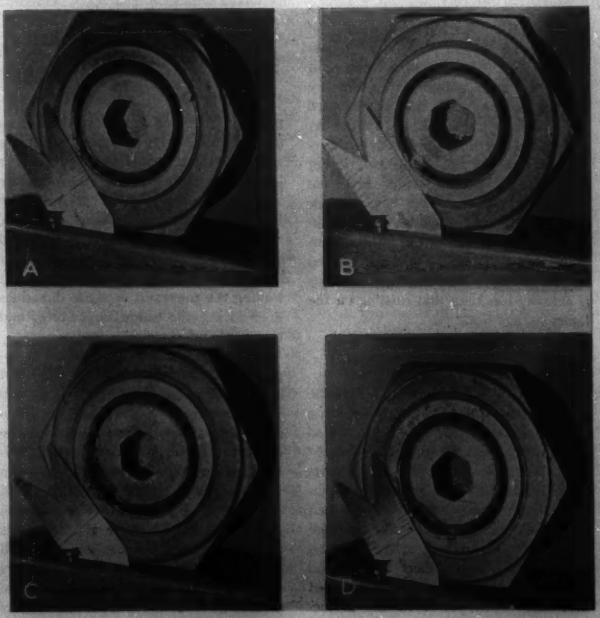
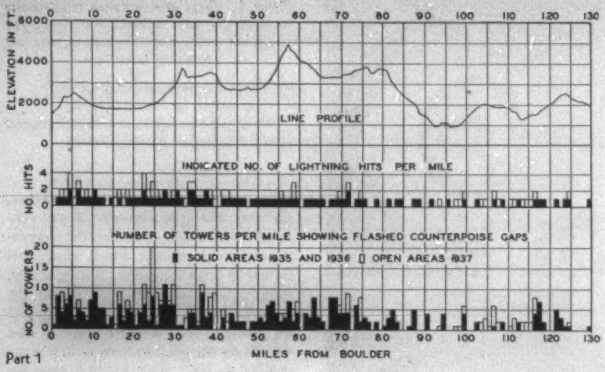
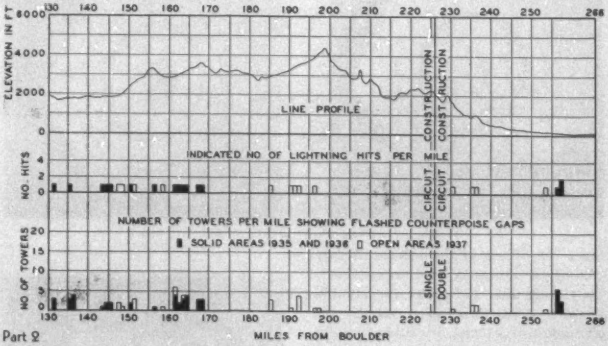



**Figure 2. Gaps used to fasten counterpoise to tower leg**

*A*—Gap from same tower as gap of figure 1 *D*. Note multiplicity of burns
*B*—Gap fused across by natural lightning
*C* and *D*—These gaps resemble power-frequency burns and appear to be the result of many strokes. Gaps burned before line was energized


ELEVATION IN FT.
LINE PROFILE
INDICATED NO. OF LIGHTNING HITS PER MILE
NO. HITS
NUMBER OF TOWERS PER MILE SHOWING FLASHED COUNTERPOISE GAPS
SOLID AREAS 1935 AND 1936 OPEN AREAS 1937
NO. OF TOWERS
MILES FROM BOULDER

Part 1




Part 2

**Figure 3. Parts 1 and 2, graphical presentation of lightning strokes per mile and number of towers affected per mile as indicated by flashed counterpoise gaps with accompanying profile of tower footing elevations**

with high-pressure jets is being used. A section of the line approximately five miles long has been washed twice to date in this manner.

At Victorville switching station, less than a mile from a large cement plant, the station insulation, switch supports, and housings are washed frequently to prevent setting of the cement dust. Jet pressures up to 800 pounds per square inch are used. The line for a distance of about ten miles through this territory is washed once a year. It is contemplated that cleaning the insulators on the remainder of the line will be unnecessary.

During the 20 months of operation of the Boulder Dam circuits involving practically two complete fog seasons, there has been no danger of flashover in the fog areas, and with the washing program being followed, the noise created by the insulators under fog conditions is actually less than that existing on the lower-voltage lines.

## Lightning Design

At the time the lightning design of the Boulder Dam line was started, lightning theory had not been developed nearly so far as at present. Direct hit theory[3,4] had a few proponents and had had its first substantiation by reasonable methods of calculation.[4,5] Counterpoise had been used successfully in one location[6] and before the erection of the line had been installed on other transmission systems.[7,8] Many of the factors used were not contemplated in the mathematical theory of lightning phenomena at that time; such as, change in stroke surge impedance with voltage, change in coupling factor due to excess voltage and corona, reduction in kilovolts per foot values for long distance flashovers, the concentration of charge on the ground surface rather than at the equivalent ground plane depth, the effect of current leaving the towers in opposite directions in reducing the surge impedance, and many other factors.

In general, classical wave theory as applied to transmission lines[4,5,9] was used as the main basis of design. The voltages encountered were based on 16 to 20 million volts in the streamer at the tower top. The streamer surge impedance used was the conventional 200-ohm value, though studies were made with other values as modified by size of corona sheath and height above ground. This variation in streamer impedance as well as the impedance of the feeder streamers or collecting paths within the cloud are considered extremely important factors in determining the current in the lightning discharge. The flashover voltages for the longer distances were extrapolated from existing curves with the slope slightly decreased in the upper regions. The theoretical corona sheath diameter was used for the capacitance element in computing coupling factors and surge impedance while the metallic conductor diameter was used for the inductive component. In the case of towers, due to the already large dimensions, physical dimensions only were used for both the inductance and capacitance elements. There is appreciable reduction in theoretical surge impedance for the case of wires leaving a junction in opposite directions. Though this effect decreases rapidly with distance, it is believed that this effect combined with the fact that the charges are located on or near the ground surface accounts for the improved performance of the counterpoise ground over the vertical ground well, even though the latter may have the lower measured resistance.

As contemplated, ground resistance measured on stakes driven to approximate counterpoise depth showed resistance values as high as 3,000 ohms, though the large concrete tower footings at their greater depth showed values from as low as one ohm up to 150 ohms, with the majority of the footings measured showing less than 10 ohms. It was realized that to attempt to terminate counterpoise wires in this high-resistance top soil layer would produce severe voltage reflections and render the counterpoise ineffective. In addition, with the equipment developed for laying the counterpoise, it was more economical in most cases to use the additional length of wire in laying a continuous counterpoise than

it would have been to attempt to cut and ground radial wires at the end of shorter runs. The continuous counterpoise was used, each wire leaving the tower radially until 135 feet apart, then turning to run parallel to the center line of the transmission circuit, thus gaining the advantage of low surge impedance of the radial counterpoise without the disadvantages of terminal reflections. In the desert section where the two single-circuit tower lines are used, there is a cross tie between the adjacent counterpoise systems of the individual circuits. This gave a theoretically lower surge impedance than would have resulted from the addition of a single wire, but with approximately a one-microsecond time delay. Arrangement of the counterpoise was given in a previous paper.[10]

The evaluation of the counterpoise surge impedance is still a debatable matter. In this design attempt was made to duplicate by calculation values that had been recorded in tests.[11] It was necessary to use correction factors to get agreement between these data and computed values, though some writers later obtained agreement by the use of two-wave theory.[12] The correction was primarily the use of a slight corona sheath or high-conductivity area in the ground and surrounding the counterpoise. That this condition exists can be indicated by surging a conductor in water of high conductivity and observing the corona formation on the conductor under the water. The other factor, primarily not a correction, was the use of a dielectric constant greater than unity for the material outside of this corona envelope. With these corrections, close agreement between theory and measured values was obtained.

Realizing the possible inaccuracy of the assumptions upon which lightning theory is based, a slight safety factor was considered desirable. The curve of flashover with ten-microsecond time lag lies approximately 12 per cent below the same curve for two-microsecond time lag. To introduce a safety factor, the curves for the ten-microsecond time lag were used for insulators and gaps, rather than the two-microsecond values as computed. Thus if the computed values were rigidly correct, the use of the ten-microsecond curves would give a 12-per cent overinsulation for the maximum lightning voltages expected, which percentage is no more than the erraticness of flashover voltage.

On the basis of these studies a 16- to 20-million-volt lightning stroke to the tower would require approximately ten feet of insulation to prevent flashover. To balance this insulation for the case of a stroke to the ground wire at the center of a 1,000- to 1,200-foot span would require a separation of 40 feet between ground wire and conductor at mid span. This balance of insulation between the supports at the tower and the separation between conductor and ground wire at mid span has been substantiated by recent literature.[13]

## Insulators

A lightning generator of the cage type was erected at the Harris J. Ryan High Voltage Laboratory, Stanford University, and with the co-operation of Doctor J. S. Carroll, studies of the effect on impulse and 60-cycle flashover of insulator separation, diameter, and shape were made on practically all commercial shapes available at the time. Assemblies up to ten feet in length were tested. Other data[14] published by eastern laboratories substantiated these measurements and furnished additional data upon which to base cost studies. This study included, in addition to the cost of insulators, the cost of added tower height and crossarm length necessary to maintain the same flashover voltage. On this basis, the 10-inch-diameter 5-inch-spaced unit showed a decided economic advantage, while the 12-inch-diameter conventionally shaped unit with a separation of $5^{3}/_{4}$ inches showed the second lowest cost based on insulator and steel prices at the time of the study. Because of these studies, the 10-inch-diameter 5-inch-spaced insulator was selected for the desert or lightning section as well as fog section of the Boulder Dam line.

## Grading Rings

Initial studies were made on a relatively large oval grading ring for the lower end of the insulator strings with a circular ring for the top end of the assembly, and their proper dimensioning and location was verified by impulse tests in the laboratory of one of the eastern manufacturers. These shields proved too costly for the improvement offered; so it was decided to use a relatively large arcing horn at the lower end of the string with a strap-type upper horn. The basis of design and positioning of these arcing horns was such that they should prevent cascading for all string flashovers occurring in three microseconds or less, and be free from corona at a voltage 20 per cent above the operating voltage. This basis was followed as an insulation standard for all of the equipment on the Boulder Dam lines. The insulator assembly has been pictured in a previous paper.[10]

## Operation and Measurements

One of the circuits was first energized for its entire length from Boulder power plant on October 9, 1936, and went into permanent operation on October 26, 1936, as described in a companion paper.[15] Thus the energized line was subjected to a few storms at the end of the 1936 lightning season and all of the 1937 season under normal operating voltage.

The line erection was started in the latter part of 1934, and approximately 27 per cent of the overhead ground wire and a somewhat larger percentage of the counterpoise had been installed by August of that year. During the 1935 lightning season, 73 per cent of the ground wire and 79 per cent of the counterpoise were installed with conductor stringing progressing to about these same values. Thus in the collection of data, the 1934 and 1935 season are considered as one year and called 100 per cent line length. The line was 100 per cent complete during practically all of the 1936 lightning season.

The counterpoise leaving the base of the tower is attached with a gap connection for the purpose of preventing electrolytic corrosion between the copper counterpoise and the zinc and steel of the tower leg. External from the tower, however, the counterpoise is continuous with the loop between the two wires of each circuit and between adjacent circuits closed at each tower to prevent building up excessive induced potentials in long isolated leads. A cross section of one of these gaps with the counterpoise wire in place is shown in *A* of figure 1. The gap is of cast bronze with molded bakelite insulation between the two elements and bolts directly to the tower leg about seven inches above the footing. The gap between the concentric cylindrical elements is $^{1}/_{16}$ inch, which offers no barrier to lightning voltages.

In addition to providing the insulation necessary to break the zinc-copper circuit, the counterpoise gaps serve to indicate the location of lightning strokes. The first indication of outstanding importance from these gaps was an observed direct hit which involved the gaps on seven towers of the two adjacent circuits. From the nature of the burns a code was developed primarily involving burn size and location and the nature of the burn. The diameter or size of the burn was given as a number indicating

twentieths of an inch; thus, a half-inch burn is a number 10 burn. Early in 1937 the gaps on the first 200 miles from Boulder were surveyed. This survey, covering the two years of erection with a few months of operation, revealed a wide variety of burns ranging from a small bead of copper about 0.02 inches in diameter to burned areas covering over one-half inch of the circumference of the gap. Other

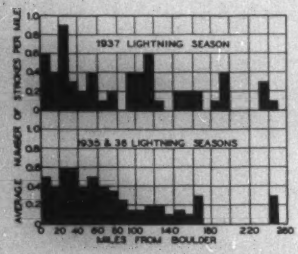



**Figure 4. Average number of lightning strokes per mile per year. Averages obtained for each ten mile section**

discharges fused the gap together in diameters in excess of $^1/_8$ inch. The code that had been developed was inadequate and had to be revised, though the measurement of the burn diameter in twentieths of an inch was retained.

At about this time published data indicated that burn size could be used as an indication of the magnitude of crest current.[12,16] The sponsor of this idea checked this effect on the counterpoise gaps using an oscillatory wave and currents from 25,000 to 100,000 amperes. The burn diameter was found to be proportional to current with approximately 0.625 inches of burn per 100,000 amperes. These burns had the character of molten metal that had been blown violently. The burn as produced by test with 75,000 amperes is shown in figure 1 *C* and is about $^9/_{20}$ inch in diameter. The burns produced by actual lightning are equal or greater in diameter than those obtained in the laboratory. Figure 1 *B* shows a burn from natural lightning of the same character as the laboratory burn that is between $^{13}/_{20}$ and $^{14}/_{20}$ inch in diameter. This would indicate a current in excess of 100,000 amperes. Figure 1 *D* shows another burn of the same nature between $^4/_{20}$ and $^5/_{20}$ inch in diameter that was obtained from a tower leg on which the magnetic-link-type surge-crest ammeter had recorded 21,000 amperes with 18.5 per cent oscillation. The magnetic links on the north leg of the same tower indicated a similar current value, but the gap showed three or more burned areas indicating the multiplicity of the strokes. The diameter of the individual burns was approximately $^3/_{20}$ inch while the laboratory data would have indicated 21,000 amperes should have burned an area between $^2/_{20}$ and $^3/_{20}$ inch.

Complete fusing of the gap occurred in only about five cases. Figure 2 *B* shows a typical case in which the diameter of the fused section is nearly $^3/_{20}$ inch. This condition is considered to be the result of many low-current strokes of a multiple discharge, or the result of a low-current long-time discharge. Figures 2 *C* and 2 *D* show two burns of a similar nature, yet much more extensive. These are assumed to be the result of multiple strokes or many strokes in the same location. These latter burns have the nature of power-frequency burns, but there have been no flashovers since the line was energized, so they are known to have been the result of lightning.

Though there is close agreement between the laboratory and field data in many cases, others show little similarity. Extreme care and considerable more data will be necessary before using the counterpoise gaps as an accurate current-measuring device, primarily because of the multiple nature of the lightning discharges with overlapping burns, the oscillation between the streamer and the lightning-protection system or within the latter, and the great variation in the time of discharge, though at present duration of discharge is considered to have little effect on diameter. Further calibration data are being obtained and it is hoped that future reports will include current values as indicated by the counterpoise gaps.

The location of the counterpoise gaps flashed by lightning is given diagrammatically in figure 3. The line profile is included in the charts. The data from the survey of May 1937 include all of the gaps that were flashed during the 1935 and 1936 seasons except those changed by construction crews and are indicated by the solid areas. The data from the survey of May 1938, covering the 1937 lightning season, are indicated by the open areas of the chart.

The upper section of the chart shows a great many more gaps flashed in the first 130 miles from Boulder Dam than in the lower section of the chart which covers the remainder of the line. This substantiates the data given by the Weather Bureau's isokeraunic charts.[1] There was a total of 110 strokes indicated during the 1935 and 1936 seasons, or an average of 55 per year, and 63 during the 1937 season. In general, less towers were involved per stroke during the 1937 season than during the previous seasons, due possibly to inaccuracies of the earlier survey or overlapping of the two seasons. With but few exceptions, the lightning is relatively evenly distributed in the first 80 miles from Boulder Dam. The lack of hits at the high point of the line in mile 32 is due to the fact that the line runs through a pass and is protected by adjacent mountains. This is also true to a lesser degree of the ridge in mile 39 and 40. For the next 30 miles, from mile 40 to 70, the 1935 and 1936 seasons showed little decrease in intensity, but the hits during the 1937 season were very scattered, being limited to sections adjacent to the high points. It was this summit at mile 57 that showed the heavy power-frequency type burns of figures 2 *C* and 2 *D* during the 1936 season. The section between mile 80 and 170 shows a decidedly lower lightning level with a still lower lightning level between mile

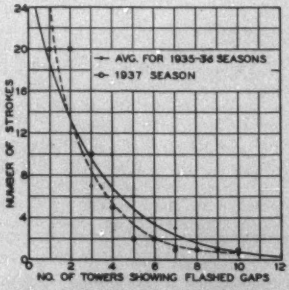



**Figure 5. Variation in lightning stroke intensity as indicated by the number of strokes affecting various numbers of towers—indication obtained from flashed counterpoise gaps**

170 and the Los Angeles terminal of the line.

The group of hits near mile 257 indicated as a 1936 hit occurred in December 1936 after the line was energized. This was in the section of double-circuit construction where the lightning protection is less effective than in the single-circuit area, due to less counterpoise and greater separation between the ground wire and lower phase wires. There was no flashover, yet the counterpoise gap burns on two adjacent towers indicated in excess of 100,000 amperes per tower.

Figure 4 gives a condensed indication of the lightning stroke intensity throughout the line. The values plotted are the average strokes per mile per year for the

ten-mile section included. The lower section using two years data shows a general trend with the number of strokes decreasing between the dam and Los Angeles. The upper section for 1937 only is very erratic in nature. There are high sections between miles 90 and 120, 140 and 170, 180 and 200, and again between miles 230 and 250. These blocks were not shown clearly by the larger plot of figure 3.

In the lower section of figure 3 is shown the number of towers per mile that showed flashed counterpoise gaps, which follows the same trend as the number of hits per mile. The duplication of hits in mile 24 produced an unusual quantity of flashed gaps yet the whole section of the line up to mile 80 showed a large number of flashed gaps. In addition to showing the lightning frequency decreasing west of mile 80, figure 3 also indicates that the intensity may be decreasing also due to the smaller number of flashed gaps for each hit. There are many more hits in this section where only one or two towers are affected.

As an indication of the distribution of stroke intensity, figure 5 shows the number of strokes that flashed counterpoise gaps on various numbers of towers from 1 to 12. The plotted dots and solid-line curve give the approximate average per year for the 1935 and 1936 seasons combined, while the plotted circles and dash-line curve cover the 1937 season. The two average curves are surprisingly close together though the individual points are erratic. From the curves it is seen that between 12 and 20 lightning strokes per year will involve but 1 or 2 towers; 4 per year, 4 towers; 2 per year, 6 and 7 towers; and a stroke every other year, or half a stroke per year, may involve 12 towers. There are, of course, those discharges that will not permanently mark the counterpoise gaps. Artificial lightning discharges of approximately 4,000 amperes show only slight discoloration with no pitting of the metal. This type discharge soon oxidizes and any record from it is lost; so that many more gaps are flashed than are actually found in the gap survey.

The number of strokes indicated may be in slight error due to some hits that were multiple in character, terminating successively on both towers yet recorded as one hit only. This increases the number of gaps per stroke, for some of the gaps flashed on the second circuit were probably due to cross currents from the preceding stroke on the other circuit and vice versa. These are located in some cases by the displacement of the centrr of disturbance on the two lines, showing how easily both circuits may be involved in open country even though 265 feet apart.

Magnetic-link-type surge-crest ammeters are installed on 23 miles of the Boulder north circuit including miles 1 to 12 and 22 to 32. Recorders are installed also on all diverter towers at the Boulder switch rack and Silver Lake and Victorville switching stations. The normal location of the supporting bracket is seven feet above the top of the concrete footing which is three feet below the first panel point. Where unequal leg extensions or irregular tower construction is involved, the supporting brackets are placed at a symmetrical point in the tower. In the normal installation there are two brace angles, $2^1/_2$ by 2 by $^3/_{16}$ inches that terminate seven feet below the link brackets. The leg members are 5 by 5 by $^5/_8$ inches so it is anticipated that the major portion of the current is carried by these leg members. From the inspection of the counterpoise gaps prior to the installation of the magnetic links stroke currents of over 200,000 amperes per tower were indicated. Since with the insulation level on these lines low-current strokes could not cause flashover, and to record more accurately the high current strokes, the magnetic links were located 6 and 18 inches from the center of gravity of the angle rather than the 3 and 9 inches as in the normal installation.

**Table I. Magnetic-Link-Surge-Crest-Ammeter Data for 1937 Lightning Season**

| Tower Number | Stroke Number | Leg | Current | Per Cent Oscillation | Cloud Polarity |
|---|---|---|---|---|---|
| 25-*N*-3 | 37–1 | N | *2,800+ | over 50 | – |
| | | E | 8,400 | 50 | – |
| | | S | 4,400 | – | – |
| | | W | 2,000 | – | – |
| | | | 17,600 | | |
| 25-*N*-4 | 37–1 | N | 21,150 | 18 | – |
| | | E | 20,800 | 18.5 | – |
| | | S | 23,300 | 19.5 | – |
| | | W | 19,150 | 21.5 | – |
| | | | 84,200 | | |
| 25-*N*-5 | 37–1 | N | *3,000 ± | over 50 | – |
| | | E | Trace | – | – |
| | | S | 5,000 | – | + |
| | | W | 3,000+ | over 50 | – |
| | | | 6,000 | | – |
| | | | 5,000 | | + |
| 26-*N*-1 | 37–1 | N | Trace | | – |
| | | E | Trace | | – |
| | | S | *2,000 ± | over 50 | – |
| | | W | Trace | | – |
| 26-*N*-5 | 37–2 | N | 8,200 | 50 ± | – |
| | | E | 9,800 | 50 ± | – |
| | | S | 3,800 | – ± | – |
| | | W | 3,600 | – ± | – |
| | | | 25,400 | | |
| 4-*N*-3 | 37–3 | N | 10,600 | 50 ± | – |
| | | E | 9,000 | 50 ± | – |
| | | S | 5,300 | 50 ± | – |
| | | W | 10,400 | 50 ± | – |
| | | | 35,300 | | |
| 22-*N*-6 | 37–4 | N | *2,000 | – | – |
| | | E | 1,600 | – | – |
| | | S | 2,000 | – | – |
| | | W | 2,400 | – | – |
| | | | 8,000 | | |
| 23-*N*-1 | 37–4 | N | 13,400 | 32 | – |
| | | E | 15,400 | 37 | – |
| | | S | 16,800 | 29 | – |
| | | W | 17,100 | 28 | – |
| | | | 62,700 | | |
| 24-*N*-5 | 37–5 | N | 15,000 | 35 | – |
| | | E | 14,000 | 44.5 | – |
| | | S | 13,200 | 42 | – |
| | | W | 13,200 | 47 | – |
| | | | 55,400 | | |
| 25-*N*-1 | 37–5 | N | *5,000 | over 50 | – |
| | | E | 4,000 | over 50 | – |
| | | S | 4,000 | over 50 | – |
| | | W | 2,000 | over 50 | – |
| | | | 15,000 | | |

* Approximate.

In addition to the above mentioned installations, magnetic-link type and paper-film type surge-crest ammeters are installed on the 12 lightning-arrester phase units at the Boulder end and the six phase units at the Los Angeles end of the circuits. To date there have been no discharges recorded by the links on the arresters, though the paper film gaps on two of the arresters at Boulder showed very small punctures, possibly due to overvoltages combined with switching surges.

Five strokes have occurred of sufficient magnitude to record accurately on the magnetic links as located. One of these strokes showed indication on four towers while the remainder registered on only one or two towers. Many other towers showed traces of magnetism too small to be of value. Table I gives the tower number, leg location, crest current, degree of oscillation, and the polarity of the recorded currents. The largest stroke recorded was in mile 25 and showed 84,000 amperes on the tower hit with 17,000 amperes in the tower adjacent to the east. On the tower to the west three of the links showed the same polarity current: namely negative, while the fourth link on the south leg showed a positive current. This is one of the locations where the adjacent circuit was struck by one of the discharges in the same stroke or by another stroke. The counterpoise cross-tie between the two circuits first contacts the south leg of the north circuit which could account for the reversed polarity on this leg and the resultant lower values of current than those found on the tower to the east of the one hit. The stroke current of this discharge was at least 100,000 amperes, and if the above analysis is correct was in excess of 120,000

amperes. The oscillation on the tower struck was 18 to 20 per cent while on the adjacent towers, 50 per cent oscillation was indicated, possibly due to the effect of strokes on the adjacent line or the difference in the speed of travel of the surge currents through the overhead ground wires and through the counterpoise system.

The next stroke, in mile 26, was relatively light showing only 25,000 amperes with approximately 50 per cent oscillation. The third stroke in mile four again showed oscillation of 50 per cent or greater with 35,000 amperes in the tower and only a trace on adjacent towers. The fourth stroke centered on tower 2-*N*-1 with 62,000 amperes in the tower and oscillation between 28 and 37 per cent. The tower to the east showed 8,000 amperes with high oscillation. The stroke current was at least 70,000 amperes. The last stroke of any magnitude terminated on tower 24-*N*-5 with 55,400 amperes in the tower and oscillation between 35 and 47 per cent. The adjacent tower to the west showed 15,000 amperes with high oscillation. The total stroke current was again in excess of 70,000 amperes.

From the records obtained with the magnetic links it is evident that the low-resistance counterpoise system allows appreciable oscillation, particularly on the towers adjacent to the tower struck. This may be true oscillation, or may be reversal of current flow due to the difference in speed of propagation of the waves over the different paths. The values of lightning stroke current recorded, to date are between 35,000 and 120,000 amperes, indicating that the lightning encountered in the western part of the United States is approaching the same intensity as that encountered in the East, and since observations of the counterpoise gaps indicate that values practically double these may be encountered at times, places the lightning currents well within the range of those encountered elsewhere.

To further the study of lightning current phenomena, a lightning rod assembly is being erected on eighty transmission structures and diverter towers. This assembly is pictured in figure 6. The sharp point on the top of the rod is graduated in tenths of an inch so that the amount burned off by various lightning strokes can be determined. The information gained from this should be of value in determining the size of strand necessary in overhead ground wire to prevent complete destruction by strokes terminating on the wires.

As a measure of the total current-time values of the lightning stroke, the fuse link assembly is added below the rods. Adjacent to the rod is mounted the bracket for supporting the magnetic-link-type surge-crest ammeter while the paper-film-gap type is mounted on the supporting steel member at the base. A device for counting the number of discharges in multiple strokes is in the process of development to fill the vacant space between the last fuse-link clip and the film-type crest ammeter. It is hoped that this equipment will add some further information as to the effect of burning of lightning strokes as well as some data on the multiple stroke currents.

## Conclusions

The insulation design selected for the fog section of the transmission line gives satisfactory performance, practically free from noise and perfectly free from outage if washed at occasional intervals as contemplated.

To date there have been 173 strokes to the Boulder Dam transmission line, none of which is known to have flashed an insulator assembly. Approximately 70 of these hits occurred since the line has been energized.

The counterpoise gaps used to break the electrolytic circuit between the tower steel and the counterpoise give very desirable indications of the towers hit by lightning and serve to give an approximate indication of the magnitude of the stroke.

Magnetic-link-type surge-crest-ammeter records have showed during one lightning season, currents as high as 84,000 amperes down a single tower and in excess of 120,000 amperes in stroke current.

The adequacy of the lightning-protection scheme has been largely substantiated by the past year's experience, and future performance will determine the exact factor of safety that was built into the lines.

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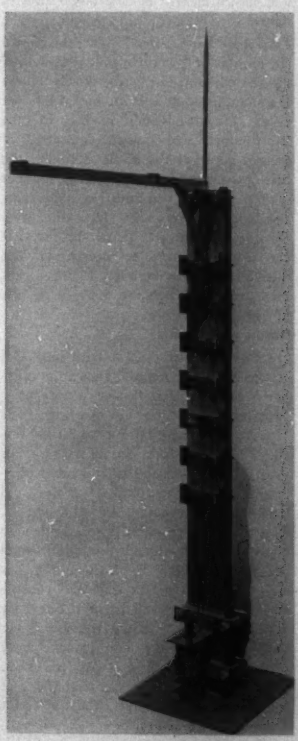

**Figure 6. Lightning rods for tower tops, points to indicate degree of stroke burning, fuse links to indicate total current times time, with magnetic link crest ammeter at top and paper film crest ammeter at base**

# Symposium on Operation of the Boulder Dam Transmission Line—Carrier-Current Equipment

By J. D. LAUGHLIN
ASSOCIATE AIEE

CARRIER-CURRENT equipment is being employed for three distinct services on the Boulder Dam transmission line: first, for pilot channels for automatic protective line relays; second, for a transmission channel for supervisory control equipment which provides control from Boulder power plant of the two switching stations between Boulder and Los Angeles; and third, for telephone communication between Los Angeles, Boulder, and the two intermediate stations, and to transmit orders to line patrolmen who may be working at any point along the line. These three functions may be performed simultaneously without interference with each other, and are not affected by power conditions or normal switching conditions on the line.

This paper deals with the supervisory control equipment, the telephone equipment, and certain equipment common to all services. The relay installation is discussed in a companion paper in this symposium entitled "Transmission Line Relay Protection."

Important savings in operating time and in investment have been achieved by the use of carrier-current equipment for these functions. As Boulder power plant is the major source of power for the City of Los Angeles, and in order to increase the stable power capability of the line, it is necessary that faults be cleared with a minimum disturbance to the system, and that outages be reduced to a minimum. The use of carrier-current pilot relays provides the high-speed relay protection for individual line sections essential to maintain stability on the system during fault conditions. The carrier-current supervisory control provides a fast means of performing switching operations on the line and reduces dispatching time by providing continuous indication at both the system load dispatcher's office and Boulder power plant of the position of all switching equipment on the line. Due to the high mechanical reliability of the line and its lightning protection, the carrier-current telephone provides a communication channel more reliable and safer than could be obtained over a telephone line built through the country traversed, and at a fraction of the cost. It also provides a quick means of issuing orders to line patrolmen and thus reduces the time required to locate and repair any faults that may occur on the line.

The term "carrier current" is used here to denote currents of high frequencies that are transmitted over the metallic circuits of the power lines to perform special functions. Since the frequencies used are of the order of those used in space transmission most of the equipment used is radio-type equipment which is directly connected to the transmission line through coupling capacitors.

The carrier-current channels all operate over the 287,000-volt conductors between Boulder switch yard and Century receiving station at Los Angeles. The relay channels stop at these stations. However, from Boulder switch yard to the power plant the supervisory and telephone carrier channels operate through coaxial cables. From Century station to the load dispatcher's office in Los Angeles the supervisory and telephone operate over direct-wire channels.

The equipment required for carrier-current transmission consists first, of radio-type transmitters that generate the carrier frequencies and are controlled by signaling devices which may be relays, if it is desired to transmit codes, or microphones for voice transmission; second, tuned coupling devices for connecting the carrier sets to the transmission line; third, the transmission line and, fourth, radio-type receivers that rectify or demodulate the messages received. There are also auxiliary devices for blocking the carrier out of stations and bypassing station equipment.

All carrier-current equipment installed on the Boulder transmission line is designed to operate at any frequency in the wave band from 50 kilocycles to 150 kilocycles, and is designed to operate at 10 kilocycles separation between adjacent-channels without interference. This band permits the use of eleven channels at this spacing, of which there are now eight channels in use and more channels will be added later. The supervisory control equipment is operating at 60 kilocycles, the telephone at 90 kilocycles, and the relay circuits at 110, 117, 130, 135, 140, and 150 kilocycles.

Each relay carrier channel operates over one line section only, and since transmission is required only when there is no fault condition on the line, one conductor and ground provide a satisfactory circuit. For the supervisory and telephone services it is necessary to maintain carrier transmission during abnormal conditions. For each of these services, one conductor in each line of a different phase is used with the midpoint between the line tuning units grounded so that if one conductor of these circuits becomes open, transmission is maintained through the other conductor and ground. Phase *A* of each line section is used exclusively for the pilot relaying carrier channels. Phase *B* of each section of the north line and phase *C* of the south line are used exclusively for the supervisory control carrier channel. Phase *C* of the north line and phase *B* of the south line are used exclusively for the telephone carrier channel.

The line coupling devices used to connect the carrier sets to the transmission line consist of a capacitor connected to the line conductor and to ground through a variable tuning inductance and one wind-

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## Discussion

For discussion see page 156.

**Figure 1. Line coupling equipment**

*A*—Wave traps
*B*—Coupling capacitor
*C*—Potential device
*D*—Supervisory line tuning unit
*E*—Relay carrier set
*F*—Telephone line tuning unit

ing of a repeating coil. There is a coupling device connected to each conductor entering the station, and a wave trap between each coupling device and the station (figures 1 and 2).

Each coupling capacitor consists of four porcelain-housed units in series, each consisting of 40 series units, using aluminum foil plates, insulated with kraft paper, giving a capacity of 0.00075 microfarad for the complete unit. The porcelain housings are evacuated, then filled with insulating oil to within several inches of the top of the metal cap. This top space is filled with an inert gas and hermetically sealed to provide a cushion to prevent excessive pressures due to expansion in hot weather.

At the lower end of the capacitor the circuit divides, one branch being a carrier-frequency circuit and the other a power-frequency circuit. A 0.03-microfarad condenser, in the carrier-frequency circuit, blocks the passage of power-frequency currents and a 0.24-henry choke coil, in the power-frequency circuit, blocks carrier-frequency currents. From the small condenser the carrier-frequency circuit goes to the line tuning units. The tuning units for the three services are slightly different in construction, but each consists of a variable inductance by means of which the circuit from line conductor through capacitor, tuning unit, and repeating coil can be tuned to resonate at any frequency between 50 kilocycles and 150 kilocycles. In order to bypass station equipment, the tuning units at the two ends of the station for the supervisory carrier are connected together with underground coaxial cables; the telephone tuning units are similarly connected. The carrier sets are connected in the circuit between the tuning units (figure 3).

The 60-cycle circuit from the radio-frequency choke is completed to ground through the primary of a potential device having a capacity of 150 watts at 115 volts to provide energy for relay potential coils. The secondary of this device is connected to an adjusting unit by means of which phase angle and ratio adjustments are made.

The wave traps in the line between the coupling capacitors and the station are adjustable to block any single frequency within the carrier band from entering the station equipment and becoming dissipated in losses in the equipment or in closed shorting and grounding switches. For the supervisory and telephone services they also force the carrier currents to go through station bypasses, and thus provide approximately the same circuit characteristics regardless of the position of station equipment. The traps used for the three services are essentially the same; they consist of a large coil shunted by adjustable groups of small fixed condensers of various sizes in series with a variometer. The inductance coil in the traps used in the relay circuits consists of 31 turns of 750,000-circular-mil cable wound on a 15-inch-diameter porcelain shell. Those used in the traps for supervisory and telephone circuits consist of 36 turns of $^{7}/_{8}$-inch diameter solid hard drawn copper rod wound in two layers of 15-inch and 19-inch diameters supported on a bakelite frame. A protective gap and lightning arrester are connected across the trap to protect the capacitors in case of high voltages due to surges on the line.

All the carrier transmitters and receivers used on the Boulder transmission line operate from 115-volt single-phase 60-cycle power supplies. To insure the best reliability for their power supply, there are, in each station, two d-c motor-driven alternators obtaining power from the station control batteries and connected through automatic transfer equipment to a carrier equipment bus. Either alternator can be connected to the bus but not both at the same time. In case the operating machine fails and the bus potential drops, the second motor is automatically started and its alternator is connected to the bus. At the same time, the motor switch of the other set is opened. In case neither set starts, the bus is connected to the station lighting supply as an emergency standby. The station lighting supply is not used normally because its regulation is not considered good enough for this service. Automatic voltage regulators on the alternators hold the carrier equipment bus voltage to within one volt. The frequency varies slightly but this is not objectionable as all of the carrier equipment operates satisfactorily at any frequency between 50 and 60 cycles per second.

## Carrier-Current Supervisory Control

### Control Scheme

The carrier-current supervisory control equipment used on the Boulder transmission line provides a centralized control at Boulder power plant of the 287,000-volt switching equipment on the line, and also operates a system diagram board in the system load dispatcher's office at Los Angeles.

The operator at Boulder can perform the following operations at both Silver

Lake and Victorville switching stations: Open and close four oil circuit breakers, open and close eight disconnect switches, open and close four ground switches. There is continuous visual indication by means of colored lamps on the control board at Boulder of the positions of all this equipment and potential indications for each line section. There are also indications for the following equipment connected to the Boulder line and located in Los Angeles over which the Boulder

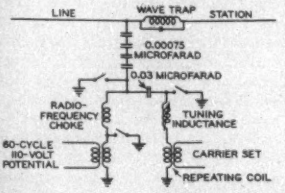


**Figure 2. Carrier-current-coupling-equipment wiring**

operator has no control: four oil circuit breakers, four disconnect switches, four ground switches, and potential on two busses. On the same benchboard with the supervisory control equipment is a panel for the control of the equipment in the Boulder switch yard. This equipment is controlled by direct wire using the same type of control switches and indicating lamps that are used on the supervisory panels. From this panel are controlled four oil circuit breakers, eight disconnect switches, and four ground switches.

On the system diagram in the Los Angeles load dispatcher's office continuous lamp indication is provided by the supervisory equipment of the positions of all oil circuit breakers, disconnect switches, ground switches, and potential on lines and busses at Boulder switch yard, Silver Lake switching station, Victorville switching station, and the equipment at Century receiving station, Los Angeles, that is connected to the Boulder lines.

The Boulder operators are responsible for keeping the lines energized to Los Angeles. In case of trouble on the line, whereby Boulder becomes separated from Los Angeles, the bus breakers at Los Angeles are opened either automatically or by the local operator, depending on the nature of the trouble. The Boulder operator then energizes the line and it is synchronized with the system by the operator at Los Angeles. The control of all line circuit breakers at the two switching stations, in such a case, is by carrier-current equipment. Normally all switching in such a case would be done without telephone communication except orders for speed adjustment for synchronizing, and this order is over carrier-current equipment.

The specifications for the carrier-current supervisory control equipment require that the carrier-current equipment shall transmit and receive signals so as successfully to operate the supervisory control equipment: (*a*) under normal transmission line conditions, (*b*) without regard to the position or operation of any air-break switch, grounding switch, or circuit breaker at any of the stations, (*c*) with any one section of the transmission line solidly grounded at any point between stations, (*d*) with one phase wire to which coupling is made broken in any one section and either or both ends of the phase wire either grounded or ungrounded at the point of failure.

These requirements cover any operating conditions that are expected to occur on the line.

## Supervisory Carrier Equipment

The carrier-current equipment for supervisory control operates at a single unmodulated frequency of 60 kilocycles, transmitting codes similar to radiotelegraph signals. The carrier equipment at the four stations are duplicates, using all industrial-type tubes. The transmitter circuit consists of a Colpitts oscillator, followed by one stage of class-*A* amplification and one stage of push-pull class-*B* amplification. Keying is done in the oscillator grid circuit. The keying relay is of the type used in high-speed radio telegraphy and operates from the 48-volt supervisory-control battery and is controlled by the supervisory relays. By selection of taps on the transmitter power transformer and by the use of either two or four tubes in the output amplifier, the sets are adjustable to operate at outputs ranging from 50 to 400 watts.

The best signal levels at all stations have been obtained with the transmitters at Boulder and Los Angeles operating at 400 watts output, and those at Silver Lake and Victorville at 200 watts output.

The receivers employ a special self-regulating heterodyne circuit. The receiver output operates a receiver relay which in turn controls the supervisory relays.

Test telephone sets are provided which can be plugged into the transmitter and receiver circuits for temporary communication.

The Boulder control board is a steel benchboard with four panels, one for Boulder switch yard, one for Silver Lake switching station, one for Victorville switching station, and one for Century receiving station at Los Angeles. On the benchboard there is provided, in a mimic bus system, an individual control key and indicating-lamp escutcheon for each piece of apparatus remotely controlled or supervised. Associated with these lamps and keys, and controlled by the operations of the keys, are groups of small multicontact relays mounted on relay panels. A similar installation of multicontact relays is made at each remote station. At the remote station, however, the relays are controlled by the operation of those at Boulder by carrier impulses transmitted over the line and are connected through their contacts to interposing relays which, in turn, cause the devices in the remote station to function in response to the operations initiated by the Boulder operator.

Separate independent codes are used for the selection of each device. For common functions such as close, trip, supervisions, Los Angeles check and release, a group of codes common to all points is used. Guard circuits are incorporated in the equipment that prevent the completion of a selection sequence if the selection code is not received correctly.

When an individual selection key is pulled on the benchboard, the Boulder transmitting relays set up and place on the line the predetermined selection code for that point. This code is transmitted from Boulder to all other stations. The function of this code is to select for operation the switch corresponding to the escutcheon on which the operator pulls out the selection key, and to select the corresponding point on the Los Angeles dispatcher's board. When the point selection code is completed, check codes are transmitted from the selected station and from Los Angeles, which cause the individual point selection lamp to be lighted on the escutcheon on the Boulder board corresponding to the equipment selected.

To close the breaker the operator now sets the individual twist type control key in the close position and then depresses the master control key. This causes the Boulder transmitting relay to send out a close code which is registered by the selected station's receiving relays and they, in turn, cause the "close" interposing relay to be energized, thus causing the power circuits to close the breaker. The closing of the breaker changes the position of its auxiliary switch, which, in turn, changes the position of the indication relay. This

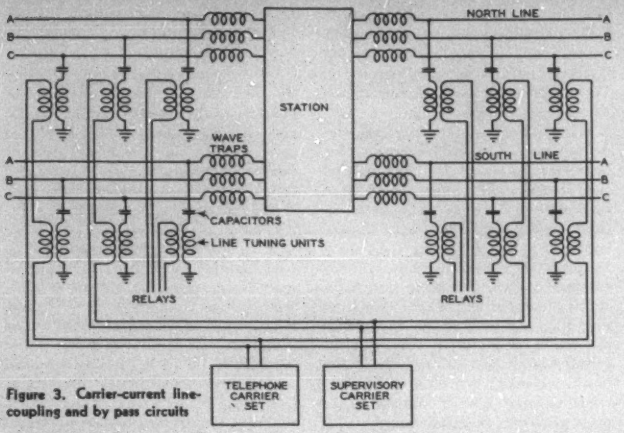


**Figure 3. Carrier-current line-coupling and by pass circuits**

relay operates to send a code which changes the position of the lamp relays for the selected breaker, thus causing the indicating lamps to change from green to red at Boulder and Los Angeles and completing the entire operation. The elapsed time from pressing the master control key until the lamps change is two seconds. Pressing the selection key resets the equipment to normal.

The operation of tripping a breaker is the same except that a trip code is transmitted to energize the "trip" interposing relay.

In case of an operation of any switching equipment by other means than by supervisory control a similar sequence occurs except that the selection code is transmitted by the equipment in the station where the operation occurred. This code is received at Boulder and Los Angeles and causes the indicating lamps to change.

Sequence of point selections is so arranged that line indications are on the first points, oil circuit breakers next, then disconnect switches and ground switches. If a line section relays due to a fault, five indications are transmitted, dead line and the opening of four oil circuit breakers, all in less than 25 seconds. If an automatic operation occurs during the sending of a code, the signal to indicate that operation is automatically withheld until the first signal is completed, and is then immediately transmitted. If a code originating in an outlying station is not correctly received at Boulder due to possible interference with the carrier or other external causes, the code is repeated until it is correctly checked or is automatically stopped after several attempts.

Interlock circuits are incorporated in the equipment that prevent the closing of a ground switch at either end of a line section if a disconnect switch is closed at either end of the section and also prevent closing a disconnect switch if a ground switch is closed at either end of the section. Circuits also prevent the operation of a disconnect switch unless its associated oil circuit breaker is open.

The equipment is so designed that trouble in any one station will not interfere with the operation of the balance of the system. Circuits are provided to sound alarms in case of a failure of the supervisory equipment. Telegraph sounders are located at the Boulder office and Los Angeles, connected in the line circuit so the operators may readily know when the supervisory is in motion.

In addition to the supervisory control all stations are provided with conventional-type remote-control switchboards and all switching equipment can also be operated manually. In case any equipment is operated from the local control boards or manually the operations are recorded by lamp changes on the supervisory boards at Boulder and Los Angeles.

### Operating Experience

After the carrier-current supervisory-control equipment was put into service it was found that extraneous signals occurred on the line with sufficient 60-kilocycle components to operate the receiver relays. These signals were generated by lightning and other discharges during rain storms, arcs that occurred when disconnecting switches were opened or closed, and transients that occurred when line sections were energized or de-energized. Any of these signals occurring during the transmission of a supervisory code would interfere with the supervisory relays registering the code properly and cause the equipment to lock out or fail to complete the operation intended. The intensity of the signals caused by rain and lightning is relatively low and could be tuned out by desensitizing the receivers; however, the signals generated by disconnect arcs and switching transients are of higher levels than the code signals during some of the abnormal line conditions under which it is required that the equipment operate. These interference signals contain other frequencies in the carrier band in addition to the 60-kilocycle component. A circuit was designed and added to the receivers that will detect these multiple-frequency signals and increase the bias on the 60-kilocycle detector tube in proportion to their intensity. This circuit reduces the rectified current due to interference signals in some cases from approximately 12 milliamperes to 0.5 milliampere which is an unobjectionable value and permits weak 60-kilocycle code signals of the order of 6 milliamperes to be rectified with no decrease in value. This circuit has eliminated one of the major troubles that has been encountered in operating this equipment.

With all sections of the line energized for normal operation the carrier transmission loss is 32 decibels. This loss is increased as sections are de-energized and grounded for maintenance work. At present there are some unusual line switching combinations that increase the carrier losses to an extent that failure of the supervisory equipment occurs but it is expected that these failures will be eliminated in the near future by increasing the transmission efficiency during abnormal line conditions.

## Carrier-Current Telephone

### Communication System

The carrier-current telephone equipment provides complete intercommunication between Boulder, Silver Lake, Victorville, and Los Angeles, on a single carrier frequency of 90 kilocycles. This telephone channel is used for load dispatching, general communication, and for giving orders and instructions to transmission-line patrolmen cruising in automobiles in the vicinity of the transmission line.

The specification requirements for abnormal operating conditions are similar to those for the supervisory control. During normal operating conditions on the line this equipment provides excellent

telephone service from the standpoint of speech quality, and provides good quality and continuity of service during abnormal line conditions. On the occasion when a double-circuit tower fell during a flood, five of the six conductors were broken, the conductor that remained in the air was one to which the telephone channel was connected and communication was maintained through this condition until a repair crew grounded this conductor.

This equipment uses the single-side-band carrier-suppressed principle of transmission. All the transmitted energy is concentrated into one side band which contains all the frequencies that are essential to reproduce the original speech. This equipment operates on a single-frequency channel for transmission in both directions and employs voice-actuated vacuum-tube circuits to start the transmitter and block the receiver when transmitting and reverses this operation when receiving. Normally the transmitter is held inoperative by the introduction of a high negative bias on the grids of the modulator tubes and the receiver is normally set to receive signals. Speech currents introduced into the transmitting circuits are at the same instant introduced into the duplex control circuit. The speech currents in the duplex control circuit act to unblock the modulator and to block the demodulator. This allows the transmitter to become operative after the receiver is blocked, thus permitting the modulated speech to be introduced into the power amplifier and thence through the coupling equipment to the transmission line. The design of the duplex circuit is such that the unblocking of the transmitter and blocking of the receiver is almost instantaneous when talking is started. A certain amount of delay is provided in the release of this circuit in order to prevent the transmitter from blocking and the receiver from unblocking between syllables or between words at average talking speeds. To prevent received speech from actuating the transmitter at the receiving terminal, the received speech operates on the duplex control circuits and prevents it from actuating the transmitter.

This equipment operates similar to a party line with selective ringing. Any station can hear all conversations on the line. Selective ringing is provided between all terminals. This is accomplished by employing an audio-frequency tone of 1,615 cycles which is controlled by conventional telephone dials. The code of audio-frequency pulses is transmitted from the calling terminal and received at all other terminals. These pulses actuate sequence switches of a type used in automatic telephone exchanges. At the receiving terminal corresponding to the code dialed, relays are operated which cause a signal bell to ring. Ring-back facility is provided so that when a bell at a station is being called a 1,615-cycle tone is transmitted back to the calling station.

A two-wire extension line is run from Century station to the main office *PBX* board in Los Angeles where telephones in the main office can be connected to the carrier system. The system load dispatcher has the right of way over all other terminals and can break into any conversation and ask for the use of the line.

Power required for the operation of this equipment is supplied from a 30-volt d-c source and from a 115-volt 60-cycle source. At one location a storage battery is used to supply the direct current and at all others copper-oxide-type rectifiers supplied from the 115-volt service. As the equipment must be ready for instant service it is always kept energized. Each equipment transmitter has a rated output of 125 watts.

Patrol cars along the transmission line are equipped with radio receivers tuned to the telephone frequency. When it is desired to issue instructions to patrolmen, the dispatcher impresses a special tone on the carrier which is received by all cars. When the patrolmen hear this tone they turn up their receivers and get whatever message is on the line. These car receivers will pick up messages at any point along the line patrol road, and the performance has been very satisfactory.

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## Discussion

For discussion see page 156.

# Symposium on Operation of the Boulder Dam Transmission Line—Transmission Line Relay Protection

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WHEN the study of these lines for the application of protective relays was started the predetermination of fault currents made it necessary to calculate all of the phase-sequence constants of the lines since none of these constants for conductors of this size and spacing was available.

The elements entering into the calculation of the positive-phase-sequence characteristics were easily determined and the proper method for their consideration has been fairly well fixed by previous practice. This was not the case for the zero-phase-sequence characteristics since the equivalent depth of the ground-return circuit could not be easily determined and there was no previous experience with a continuous buried counterpoise such as was to be used with this line. In making these calculations the equivalent depth of the ground return circuit was taken as 8,800 feet and the counterpoise was considered as though it did not make contact with the earth, or in other words as though it was part of the overhead ground wire system. The depth of the ground-return circuit used which corresponded to

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1. For all numbered references, see list at end of paper.

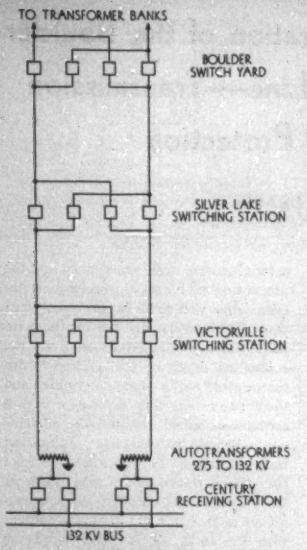


**Figure 1. One-line diagram of Boulder Dam transmission line**

dry earth was probably somewhat small for the territory over which this line was to be built and would consequently give values of impedance that were low; on the other hand, considering the counterpoise as not being in contact with the earth should give values of impedance which were high. Because of the manner in which these two factors entered into the calculation of the zero-phase-sequence impedance of the line it was believed that the final results would, if anything, be slightly high, and since they were to be used in determining the minimum current conditions for protective relays this was far more desirable than impedance values which might be low.

The line constants were first calculated for 50 cycles and a complete study of the short-circuit currents and voltages for all types of faults at each bussing point on the line was made. From this study it was apparent that if the shunt capacitance of the line was neglected the errors in current and potential, while quite large at some locations, were small at the locations under consideration in this study, and were entirely negligible at the locations which would be most difficult to protect.

When it was definitely decided that the system frequency would be changed from 50 cycles to 60 cycles it was a comparatively simple matter to recalculate the line characteristics, since a great deal of the work done during the 50-cycle calculation was not changed, and in view of the negligible errors introduced by neglecting shunt capacitance during the 50-cycle short-circuit study, it was decided to neglect this capacity in the 60-cycle study. The results of the 60-cycle study for three-phase and single-phase-to-ground faults have since been checked, using the distributed constants of the line and the above decision was entirely justified by these checks.

The results of the short-circuit study indicated that, under minimum fault conditions, the current available for operation of the protective relays would be less than the maximum load current the line would be required to carry, that the most difficult fault to clear would be a phase-to-ground fault on the 132-kv side of the autotransformers at Century receiving station and that with a phase-to-ground fault at this location when the parallel circuit was out of service the relays at Victorville could not be expected to function unless the delta connection of the autotransformer tertiary winding was opened.

## Trials of Equipment

Carrier-current pilot protection seemed most desirable for these lines; however, it was felt that some operating experience with this type of protection should be had before a definite decision was made. Equipment of this type was purchased and installed on two parallel 132-kv transmission lines, together with a scheme of balanced current protection.

Two different types of carrier pilot protection were used; one line was equipped with an intermittent carrier type in which carrier current is only transmitted when a blocking impulse is desired, because of external fault; the other line was equipped with a continuous carrier type in which carrier current is transmitted continuously, and only stopped at both ends when an internal fault occurs on the line. Both types performed quite satisfactorily during faults on the system, both internal and external, but the continuous carrier type had the disadvantages that it caused interference on nearby broadcast receivers, and that the tubes in this type were required to carry plate current continuously.

The broadcast interference was due to the fact that it was impractical to operate the transmitters at the two ends of the line at exactly the same frequency and therefore an audible beat frequency equal to the difference between the two transmitter frequencies was produced. This audible beat frequency was heard in nearby broadcast receivers whenever these receivers were tuned near some multiple of either of the transmitter frequencies.

While no trouble of a serious nature was encountered with either of these equipments, other than that described above, the experience gained proved very valuable in preparing specifications for the Boulder line relays and in adjusting that equipment when it was installed.

## Specifications

In addition to all of the ordinary features that would be required of any scheme of line protection the following special requirements were considered highly desirable in the Boulder line protection: (1) all faults on these lines should be cleared in not to exceed 0.15 second from the inception of the fault, until the last breaker was open, and (2) the protection should be immune to operation on an out-of-step or surging condition. The only types of protection that would possibly fulfill both of these special requirements are high-speed current balance protection and carrier-current pilot protection.

The maximum time required by the oil circuit breaker on these lines is three cycles or 0.05 second, and at the time the specifications were written it was uncertain if operating time shorter than 0.05 second could be obtained with carrier-current relays. This would mean that the settings of the carrier-current relays would have to be sufficiently sensitive to secure simultaneous operation of the relays at the two ends of a line section, or the total time would be extended beyond 0.15 second. Such low settings were undesirable and could be eliminated by the installation of high-speed current balance relays which would operate in 0.025 second or less so that even with full cascade operation of the relays and breakers at the two ends of a line section the total clearing time would not exceed 0.15 second.

The specifications were prepared on the basis of using both carrier-current pilot protection and high-speed current balance protection and the following performance requirements written in: The current balance protection shall operate simultaneously at both ends of a faulty circuit for any fault occurring within the center 70 per cent of the electrical length of the circuit but may operate sequentially for faults occurring within 15 per cent of the electrical length of the line from either end. The time required by the relays in

either case shall not exceed 0.025 second. With one circuit of a section carrying 300,000 kva and the other circuit open, the circuit carrying the load shall not be tripped when the other circuit is closed at either end.

The carrier-current pilot protection as a whole shall:

1. With minimum system condition and both circuits of the section in service energize the oil circuit breaker trip circuits at both ends of a faulty circuit in not to exceed 0.05 second for all faults occurring within the center 70 per cent of the electrical length of the circuit.

2. With minimum system condition and both circuits of the section in service energize the oil circuit breaker trip circuits at the end of a faulty circuit adjacent to the fault in not to exceed 0.05 second for all faults occurring within 15 per cent of the electrical length of the line from that end, and shall energize the oil circuit breaker trip circuits at the end remote from the fault in not to exceed 0.05 second after the circuit is opened at the end adjacent to the fault. The above time requirement may be exceeded if all voltages are less than five per cent of normal and no secondary current is greater than ten amperes.

3. Not cause tripping for instability or external faults under any condition.

4. Clear ground faults occurring while the system is unstable without any purposely introduced time delay.

5. Clear phase-to-phase and three-phase faults occurring while the system is unstable with the minimum practical delay consistent with the requirement that instability shall not cause tripping.

6. Remain inoperative with a load of 300,000 kva on any one circuit and no fault on the system.

7. Not delay tripping for internal faults that occur immediately after any external fault except a three-phase external fault.

8. Be entirely self-contained and shall not depend upon the operation of any piece of apparatus not directly associated with the line protected.

Other requirements of a special nature were an automatic complete carrier transmission and reception check in both directions once every hour, and a pair of portable telephones that could be plugged into the relay carrier sets at the two ends of a circuit for temporary communication during adjustments.

## Description of Equipment

Four high-speed current balance relays are used for each end of a pair of circuits, three for phase faults and one for ground faults. Each relay has two balance beam units and each unit is equipped with four coils and circuit-closing contacts for tripping two breakers. The coils are a current operating coil, a current restraint coil, a voltage restraint coil, and a d-c holding coil. The current operating coil of one unit is connected in series with the current restraint coil of the other unit, thus forming two separate current circuits for the relay which are connected one in the same phase-current-transformer secondary circuit of each line. The units trip the two oil circuit breakers associated with the line supplying their operating current.

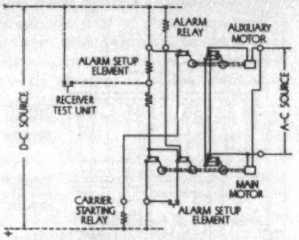


**Figure 2. Diagram of automatic carrier test relay showing internal and external connections**

The voltage restraint coils of the phase relays are supplied with phase-to-phase voltage, which leads the current used on the relay by 30 degrees at unity power factor. The voltage restraint coil on the ground relay is not ordinarily used.

A carrier-current pilot relay is used in which all of the necessary relay elements for the complete protection of a line terminal are incorporated in one case. This relay and the scheme of protection used is the same as described by Traver and Bancker,[1] except that two ground-fault detector elements are used and the functions of the ground-fault detector in the relay described are divided between these two in the same manner as they are with the phase fault detectors. In addition a normally open contact on the *A* ground-fault detector shunts the contacts of the block cut-off and block continuing units in the master oscillator grid circuit to prevent any delay in tripping ground faults occurring during instability.

An automatic carrier test relay and two auxiliary interposing relays in separate cases are used for each line circuit terminal in addition to the carrier pilot relay. The interposing relays are used one between the automatic carrier test relay and the master oscillator grid circuit, and the other between automatic test relay and the alarm circuits. A schematic circuit diagram of the automatic carrier test is shown in figure 2. The automatic carrier test relay contains a main and an auxiliary sychronous-motor-driven cam shaft, and an alarm setup relay element. The motors receive energy from the capacitor potential devices connected directly to the line and the main motor operates continuously, driving its cam shaft at one revolution per hour and operating three separate sets of contacts at 20-minute intervals. The auxiliary motor drives its cam shaft at the rate of four revolutions per minute but it is controlled by one set of contacts on the main cam shaft in such a manner that it only travels one revolution, in two steps of approximately one-half revolution each, for each revolution of the main cam shaft. A set of contacts actuated by the auxiliary cam shaft causes the carrier transmitter to operate for a period of 0.5 second and the only function of the auxiliary motor and cam shaft is to obtain this very short operation of the carrier transmitter, which could not be reliably obtained with a contact actuated directly by the slower-moving main cam shaft. Twenty minutes after the operation of the first set of contacts on the main cam shaft the second set of contacts picks up the alarm setup relay element which locks itself in, then 20 minutes later the third set of contacts on the main cam shaft completes the alarm circuit unless the alarm setup relay element has been released in the meantime by operation of the receiver test unit in the carrier pilot relay.

The main cam shafts on the automatic test relays at the two ends of a line circuit are set 180 degrees or 30 minutes apart and always remain in the same relative positions since they are always energized and de-energized together, thus carrier is transmitted from the remote end of the circuit midway between the operation of the second and third set of local contacts and no alarm will be given unless the carrier signal is not received locally. The receiver test unit has a pickup setting that is 25 per cent greater than the receiver blocking unit so that the gradual reduction of the received carrier signal which might be caused by the falling off in emission of a tube will give an alarm before actual failure has taken place.

The portable telephones can be plugged in either at the relays or at the carrier sets and a transfer circuit is arranged so that the portable telephones can be set up at the carrier sets on one line but the carrier sets on the other line used for communication. The circuits are so arranged that the operation of the carrier test, either manual or automatic, or the use of the portable telephones will not in any way interfere with the correct operation of the relays should a fault occur while any of these were in operation.

The carrier sets are contained in double-walled thermal-insulated metal cabinets which are mounted on the switch rack near the coupling capacitors. These sets consist of a line tuning and safety panel, a transmitter-receiver shelf, and a power rectifier shelf. The transmitter is a single-tube master oscillator with a push-pull type amplifier and has an output of approximately 25 watts. The receiver uses a single three-element tube of the same type used in the oscillator and amplifier. All tubes are biased to cut off when no signal is being transmitted or received. Grid bias voltage is obtained directly from the station control battery and the filament and plate supply is obtained from motor generators which are driven from the control battery.

Copper-oxide rectifiers are used as valves in the tripping circuits of all oil circuit breakers, as shown in figure 3, to prevent false tripping in the event these trip circuits should be tied together through the contacts of some of the protective relays which are blocked either automatically or manually. This is believed to be the first time copper-oxide rectifiers were ever used for this purpose, and saves the time of auxiliary tripping relays or the complication of a pallet switch interlock scheme which might be used for the same purpose.

Potential for the relays is obtained from three capacitor potential devices connected directly to each line end at all points except Century receiving station where potential for all the relays except the automatic test relay is obtained from either of the two 132-kv bus potential transformer banks through a manually operated transfer relay. The auto-test relays at this station are supplied from a single capacitor potential device connected directly to each line.

Current is supplied from cascade-type current transformers in the impulse-type oil circuit breakers at all locations except Boulder, where the conventional bushing-type current transformers on the oil circuit breaker bushings are used.

The relay carrier sets are coupled between *A* phase and ground on all circuits using the same coupling capacitors as are used for the potential devices. A wave trap which can be tuned to any frequency from 50 to 150 kilocycles is connected into the line at each end between the coupling capacitor and the station.

A single-pole oil circuit breaker is installed in the delta connection of the tertiary windings on each of the auto-transformer banks at Century receiving station. This breaker is for the sole purpose of opening this delta connection in

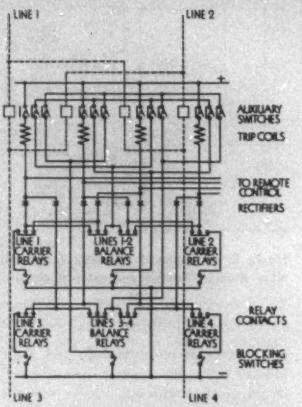


**Figure 3. Schematic diagram of tripping circuits showing use of copper-oxide rectifiers**

the event of a phase-to-ground fault between the bank and the 132-kv breakers, when the parallel line circuit is out of service, so that sufficient residual current will flow at Victorville to operate the relays at that point. This single-pole breaker is tripped by an inverse-time excess-current relay operated by circulating current in the delta connection. A minimum time setting of approximately 0.3 second will prevent this relay from operating under conditions when it is not necessary and will allow it to operate when necessary in a sufficiently short time to prevent serious damage by the fault. System stability will not be affected by the time of operation of this relay because, under the condition when it is necessary for this relay to operate, the system will have been separated from Boulder power plant and the fault by the carrier-current protection at Century receiving station.

High-voltage leading-current protection is installed on these lines at Century receiving station that will automatically open both lines in the event the lines should be opened at Silver Lake switching station or at Boulder and the leading kilovolt-amperes of the lines should cause high voltage on the receiving-station bus.

## Tests

The high-speed current balance relays and the carrier-current pilot relays were all tested at the factory, using two test tables as described by Traver and Bancker[1] to simulate the actual line conditions under which these relays would be required to operate in service. Two of the carrier sets which were to be used with these relays on the line were used in the tests and coupled together through an artificial transmission line. All types of faults, both internal and external as well as out-of-step and surging conditions in which the electrical center of the system fell within and outside of the protected line were tried. Oscillograms were taken of each test and the operations of the relays were entirely satisfactory. As a matter of fact the tripping time of the carrier-current relays was considerably shorter than was required by the specifications due to the development of the so-called one-cycle scheme of carrier-current protection between the time of writing the specifications and the start of manufacture of the equipment.

## Installation

Upon receipt of the equipment at Los Angeles each element of the relays was checked to make sure that the adjustments had not been disturbed during transportation. Carrier frequencies between 110 and 150 kilocycles were assigned to the various circuits, an attempt being made to keep as wide a separation as possible between the frequencies assigned to parallel circuits and to circuits terminating in the same stations. The wave traps for each section were tuned before installation and marked for the station, line, and phase in which they were to be installed.

The carrier sets were installed and ready to operate before work was completed on the lines themselves and to save time it was decided to adjust these sets without interfering in any way with the work on the line and to check these adjustments when the line was completed, making any readjustments necessary at that time. To make these adjustments a ground was placed on the line side of the coupling capacitors and a noninductive resistor connected in series with the carrier lead-in wire to limit the output of the transmitters. A resonant-type wave meter was used to set the oscillators to their assigned frequencies and then, using the transmitters as a source, the line coupling and the receiver primary and secondary were tuned to resonance. The coupling of the oscillator transformer and the receiver transformer were adjusted at the same time. After all sets had been adjusted by this method and the lines had been completed a check was made between the two ends of each line circuit, which revealed that operation would have been entirely satisfactory on all circuits without any further adjustments and the

only improvement that could be made was a readjustment of the receiver primary tuning, which increased the received signal by a very slight amount. The usual wiring check and over-all tripping tests were made before placing the relays in service.

## Operating Experience

The amount of trouble experienced with the protective equipment on these lines is considered remarkably small in view of the size and extent of this project. What trouble has been experienced can be classified under four different headings, (1) vacuum tubes, (2) rectifiers, (3) wave traps, and (4) switching transients.

### (1) Vacuum Tubes

This trouble is hardly worthy of mention in that out of a total of 60 vacuum tubes used in the relay carrier sets, one rectifier tube has failed in a year of continuous operation.

### (2) Rectifiers

Potential restraint for the phase-fault detector elements of the carrier-current relays is secured from the line potential devices through full-wave copper-oxide rectifiers. This is done to secure pickup characteristics of these elements which are practically independent of phase angle and to reduce the potential burden of the relay. Shortly after the line was placed in service these rectifiers failed in one of the relays. The failure occurred at a desert switching station which was the highest voltage point of the line under the operating condition at that time and where the ambient temperature was high, although not unusually so for that location. Upon investigation it was found that these rectifiers at all locations were operating at temperatures higher than were desirable and additional ventilation was provided by portable electric fans as a temporary remedy and no further trouble was experienced. New rectifiers of the same type but with 28 per cent more plates were installed and a resistor, which was the principal source of heat in the relay case where the rectifiers are mounted, was replaced by an external resistor. Since this change was made the equipment has been in operation through a summer season without undue heating of the rectifiers and no further trouble has been experienced.

### (3) Wave Traps

The line wave traps used with the carrier relays were tuned to resonance at the assigned frequency by a group of fixed condensers and a variable condenser which was used to obtain capacities in between those that could be obtained by different grouping of the fixed condensers. Shortly after the beginning of the lightning season along the line failure of carrier was indicated on one circuit by the operation of the automatic carrier test alarm. Upon investigation the trouble was located in one of the line wave traps. Flashover had occurred between the plates of the variable condenser and had eventually built up a globule of the plate material which shorted the condenser and detuned the trap. This same trouble occurred on several other traps at various times and in each case was revealed by the automatic test equipment within a few minutes after it had occurred. As a temporary expedient the short was removed with a file in each case and the trap returned to service. As a permanent cure the variable condensers were replaced by a small variable inductance in series with a group of fixed condensers and this has apparently completely eliminated the trouble.

### (4) Switching Transients

When switching operations are carried out on these lines quite large transient currents flow. The only time these transient currents have caused trouble with the relays is when a line circuit is picked up at normal voltage or when an unloaded circuit is paralleled with a circuit that is carrying load. All trouble experienced has been with the ground relays. Numerous oscillograms have been taken which reveal that these transients have frequencies from 120 cycles to upward of 700 cycles per second with or without a d-c component. The d-c component appears when an unloaded circuit is paralleled with a loaded circuit and also when a circuit containing the autotransformers is energized. The high-frequency transient appears in practically all cases but is apparently suppressed when the d-c component is present.

The minimum pickup of the balance current ground relays was increased from one ampere to two amperes at all locations and in addition at Century receiving station these relays were further desensitized for a short period of time after paralleling the two circuits by energizing the potential restraint coils from the control battery when one or both circuits are open, and removing this potential restraint automatically approximately two seconds after the lines are paralleled. This method has apparently cured the trouble in so far as the current balance relays are concerned, and since it introduces no objectionable restrictions to their operation on faults is considered as permanent.

The minimum pickup of the ground-fault detector elements in the carrier-current pilot protection was increased from 1 ampere to 3 amperes for the starting, or *A* detectors, and from $1^1/_4$ amperes to 4 amperes for the tripping, or *B* detectors. No trouble has been experienced since these settings were increased and they are still sufficiently low to clear all ground faults; however, this method is objectionable because under some minimum conditions the time of clearing will be extended longer than is desirable.

A transient filter has been developed for use with the ground tripping fault detector that will effectively block all frequencies of 120 cycles and above, as well as d-c transients, from the fault-detector coil without materially affecting the pickup characteristic of the detector on frequencies from 35 cycles to 85 cycles. These filters are being manufactured at the present time and when installed will permit resetting the ground-fault detectors to their original pickup values. No filter will be used with the starting-fault detector since there is no objection to its operation by the transient currents.

During the extremely severe flood conditions of March 2, 1938, one of the twin-circuit towers on the Victorville-Century section of the lines was washed out, causing a fault first on the north line and six minutes later on the south line. The north line was cleared by the balanced current protection at both Victorville and Century in a total time of $3^1/_2$ cycles. The south line was cleared by the carrier-current protection in $5^1/_2$ cycles at Century and $10^1/_2$ cycles at Victorville.

The fault on each line was single-phase-to-ground and the longer time required at Victorville was due to the ground current being only slightly above the pickup settings of the ground-fault detector elements. If the transient filters described above had been installed at this time and the pickup settings of the ground-fault detectors restored to their original values, the time required for clearing the south line at Victorville would have been considerably reduced and would probably have been of the same order as the time at Century.

These faults, as well as numerous other faults which have occurred on the system at various times, have demonstrated the ability of the carrier-current protection properly to block tripping on through fault conditions.

During the oscillographic investigations of the switching transients simul-

taneous records at the two ends of a 90-mile circuit were obtained in the following manner: Load was being carried over one circuit between Boulder and Victorville and records of the terminal conditions of the loaded circuit at both Boulder and Silver Lake and the Silver Lake terminal conditions of the dead Silver Lake-Victorville circuit were desired at the instant of energizing the Silver Lake-Victorville circuit at Silver Lake. A six-element oscillograph was used at Boulder, and two oscillographs, a nine-element and a three-element, with their drums mechanically tied together, were used at Silver Lake, giving six elements for each line terminal being considered. A contact on the drum shafts at each station was used to sound a buzzer once for each revolution of the drums The control circuit for the oscillograph shutter and oil circuit breaker closing at Silver Lake were arranged so that by closing a single contact both functions would occur in the proper order to obtain a record of the change in line terminal conditions when the breaker contacts closed. The control circuit for the oscillograph shutter at Boulder was arranged in the same way so that all that was necessary was to synchronize the film drums at the two stations and close the initiating contacts in both stations at the same time. The synchronization of the film drums was accomplished by placing the buzzer at Boulder near the microphone of the carrier telephone; the operator at Silver Lake was then able to hear both buzzers and adjusted the speed of the Silver Lake film drum until both buzzers sounded at the same time.

The operation of the initiating contacts at the same time was accomplished by taking the carrier-current supervisory control equipment out of service and using the receiver relay at both Boulder and Silver Lake to close the initiating circuits. When all was in readiness the operator at Silver Lake synchronized the film drums and then pressed a button, which started the local supervisory-control carrier transmitter.

The carrier signal being received at both stations simultaneously, closed both initiating contacts at the same time. The drum speeds used gave a total record of approximately 30 cycles and not a single shot was missed because of this method.

## References


1. A Faster Carrier Pilot Relay System, O. C. Traver and E. H. Bancker. AIEE Transactions, volume 55, June 1936, pages 688–96.

2. A Single Element Polyphase Directional Relay, A. J. McConnell. AIEE Transactions, volume 56, January 1937, pages 77–80 and 113.


## Discussion

**Abe Tilles** (University of California, Berkeley): I am certain that I speak for all present in expressing thanks to the Department of Water and Power for their broadmindedness in making public these interesting details regarding the few items of trouble that have occurred.

A number of questions come to mind regarding this outstanding transmission project. I am not sure to which member of this Department of Water and Power team of experts each of these questions falls, but I believe they will be able to sort them out without difficulty.

It was mentioned that the sending-end voltage of the line is being altered as the load varies. To what degree of refinement has it been found desirable to do this? Is the voltage setting changed manually by the operator in accordance with the load schedule, or is the voltage regulator initially adjusted to give continuous compounding of the generator voltage? How long does it take to put a generator on the line from a standstill? To what extent is automatic synchronizing equipment in use at present? What is the procedure in energizing the line?

It was mentioned that control and relaying equipment for the contemplated third line will fit along side of, and be similar to, the existing equipment. Is this the case at the switching stations as well as at Boulder? How far physically will the third line be from the others? Will it be generally similar and divided into sections? With three lines in parallel complications arise in a scheme of high-speed parallel protection. How, in a general way, will the three lines be protected? If the receiving third of the third line is not directly in parallel, can the carrier-controlled relaying on that section be sped up?

It was mentioned that tube failures in the carrier relay circuit act to operate an alarm. Is my understanding correct that the worst possible condition the failure of the carrier relay equipment can produce is the tripping out of a line section on a through fault? Has this ever happened?

It would seem that a failure in the tube circuits of the supervisory control equipment at the control point, if it occurred in just the right place at just the wrong time, might cause serious operating difficulties. What are the most drastic consequences which it is supposed might on rare occasions occur? How long would it take to isolate and replace such faulty tubes, etc.?

The performance expected of this project was of such an unusually high caliber, and many of the technical features were so far developed beyond previous practice, that it is no small achievement for these gentlemen to be able to say that this transmission project is living up to their expectations. To single out one item for example, the lightning record of the line is worthy of attention. Here, at last, is a line that "can take it." Three years of lightning, including a large number and variety of recorded direct strokes have not produced a single insulation failure. This is what was expected. True. It is none the less awe-inspiring to contemplate the proved fact.

These gentlemen of the Department of Water and Power of the City of Los Angeles are, indeed, to be congratulated on the results of their labors.

**K. B. McEachron** (General Electric Company, Pittsfield, Mass.): Those who are concerned with the protection of transmission lines from the effects of lightning are naturally much interested in learning of the excellent results obtained with the Boulder Dam transmission line as described by Mr. Cozzens. The experience records obtained add materially to the existing knowledge of lightning. I am especially interested because most of the lightning data obtained thus far have been secured in the East, and yet the results from the Boulder Dam transmission line agree very well in general with what would be expected, based on results obtained in the eastern part of the United States. This tends to support the general conclusion that lightning is not particularly different in the western part of the country than it is in the East. If the general conclusions can be substantiated, it will make the large amount of data already obtained of greater value, since it becomes more widely applicable. There is no doubt but that the severity of lightning storms are related to meteorological conditions, which are of course different in different parts of the country, which consideration would lead one to expect to find variations with respect to localities widely separated. These variations, if they exist, may however be covered up by other variations which have not been recognized.

Mr. Cozzens used a stroke surge impedance of 200 ohms, which, at the time the line was designed, and still is, a value used frequently when making line flashover calculations. I believe that considerable doubt surrounds the use of a surge impedance for a stroke channel, but the results obtained using values ranging from 200 ohms to 400 ohms have been reasonable, and experience seems to show that the answer obtained using such surge impedances is about right.

I do not believe, however, that the mechanism of discharge is at all similar to the discharge of a charged capacitance through a conductor. In the case of outdoor lightning, the cloud consists of charged drops of water or particles of ice separated by an air dielectric. At the time a stepped leader leaves the cloud to progress toward the ground in a series of steps, charges of opposite sign to that of the base of the cloud are accumulated on the ground These charges, usually positive in sign, because the cloud seems to be usually negative, can move in toward the point to be struck with little voltage drop where conducting objects like counterpoises are available for carrying the charges. As the negative leader progresses, requiring often as long as 0.01 second to reach the earth, it produces a space charge around its own channel.

When the downcoming leader is within a few hundred feet of the ground, the increase in field intensity on the surface of the earth is often sufficient to cause a concentration of charge at the point to be struck of a magnitude which forms streamers

which may extend several feet from the earth. These streamers increase in length as the downcoming leader approaches, until the leader makes contact, presumably with the longest streamer, after which the return stroke takes place between the earth and the cloud.

McEachron and McMorris ("The Lightning Stroke: Mechanism of Discharge," *General Electric Review*, October 1936) have suggested that the current builds up to a maximum during the time occupied by the step leader in traversing the last few hundred feet from the earth. The maximum current occurs at the time of contact, and as far as the current wave through the stricken object is concerned, the wave tail takes place during the return stroke. If this return stroke fails, as it sometimes does, to reach the cloud, it is possible to calculate the length of the tail, knowing the rate of propagation of the return stroke. On the other hand, if the return stroke reaches the cloud, the length of the tail will be dependent upon the conditions in the cloud. Additional charge may be available, or new regions tapped in the cloud, giving rise to a long tail or to a multiple stroke.

With this conception, the rate of rise of current is dependent upon the amount of charge in the leader and its rate of propagation. The maximum current is dependent upon the amount of charge and its availability on the ground at the point struck. The tail of the wave results from the flow of charge from the earth into the channel created by the leader.

Data are not yet available to support completely the foregoing, but nevertheless sufficient data are at hand to indicate strongly the probability of the mechanism indicated. Propagation data on a large number of strokes are available, and the existence of streamers up from the ground has been identified through photographic evidence. Much remains to be done, and work is actually progressing, which should add materially to the information available as to just what does happen at the instant of contact.

Mr. Cozzens has commented on the presence of corona in the ground around the counterpoise wires. There is no doubt that corona and sparks exist when the potential of the counterpoise is high enough. Impulse tests on ground rods of fairly high resistance earth have shown reductions of the order of 40 per cent in resistance compared to the low-voltage measurements. Corona, coupled with a series and multiple gap effect, no doubt played an important part in this reduction.

Under the heading "Operation and Measurements," Mr. Cozzens discusses the size and character of the burn on the tower gap in relation to the magnitude of the current flowing through the gap. There is no question in my mind but that considerable information can be obtained in this manner. However, I do wish to point out that there is considerably more to this picture than the current amplitude. In the studies of lightning to the Empire State Building (*EE, Dec. '38, p. 493–505*), I describe a type of stroke which I have called "continuing," which is really a d-c arc between the cloud and the ground. In one case, a current of the order of 250 amperes or more flowed for a time of 0.51 second or slightly longer than a period corresponding to 30 cycles of the usual power-frequency supply. This particular stroke had a superimposed peak of 13,000 amperes together with many smaller peaks. These results are obtained from an oscillogram of the stroke.

Laboratory tests show clearly that the type of burn to which Mr. Cozzens referred as resembling a 60-cycle burn can be caused by a continuing stroke. Burns showing beads are not as a rule associated with high-current short-time discharges but with the longer time discharges, which will, in general, be of much lower magnitude, although they may have high superimposed peaks. This situation, of which I have obtained oscillographic evidence in which the explosive effects of high-current short-time discharges are combined with the burning effects of low-current long-time discharges tends to confuse the story to be obtained from burns on gaps, at least in some cases.

Mr. Cozzens also suggests the possibility of multiple strokes moving across a distance of 265 feet from one tower line to the other. Such a possibility seems very remote to me in view of our latest data. The maximum time of discharge of which I am aware is 1.53 seconds obtained in 1937 in New York City. It would require a 118 mile wind and a stroke duration of 1.53 seconds to affect both lines from the point of view of blowing the discharge path from one circuit to the other. Such a combination of high wind at right angles to the line, and of maximum duration, is extremely doubtful. There is one other possible explanation, but it too is not likely to occur. I have photographic records of two multiple strokes which changed their paths on the ground end between successive strokes a distance of several hundred feet, apparently due to change in local ionization conditions. This phenomenon is most unusual, which might be invoked to explain the results obtained by Mr. Cozzens. It seems more likely to me that the strokes were successive in the same storm but not in the same stroke.

**P. L. Bellaschi** (Westinghouse Electric and Manufacturing Company, Sharon, Pa.): One feature which distinguishes this investigation is that Mr. Cozzens has availed himself of a number of suitable and simple devices to measure the lightning currents to the line. From each, one or more characteristics of the lightning stroke are recorded and from the combined recorded effects a more complete appraisal is possible both in regard to the current amplitude, the duration, and also other characteristics of the discharge.

The writer has long advocated that advantage must be taken of all suitable means if lightning phenomena are to be investigated on a comprehensive basis. The magnetic link has shown its usefulness in recording the crest of the current—an important factor to know in lightning protection. Surface burning of metal parts, such as the tower gaps on the Boulder Dam line, and in addition fusion of metal links and other similar means contribute to determine the current amplitude and the nature of the discharge.

For example, test results obtained at Sharon during the past year have established that currents in the order of a few thousand amperes sustained several thousand microseconds produce concentrated fusion effects similar to that in figure 2*B*. As it already had been suspected a few years ago, this fusion apparently results from such current components being present in the discharge of certain lightning strokes. The concentrated arc and sustained arc drop of these current components thus produce fusion effects resembling those of the power arc.

In this connection the photographic studies during the past five years by Doctor B. F. J. Schonland and his associates ("Progressive Lightning—III," *Proceedings of the Royal Society*, September 1937) clearly show that the high current, which results from the main stroke discharging from earth into the established channel and the main branches, takes place in some 100 microseconds. This intense discharge is followed by a sequence of moderate current components extending into hundreds and even thousands of microseconds. The source of these current components seems to reside largely in the cloud and are due to a continuation of the lightning discharge in the cloud proper. While visual accuracy may be questioned, it is apparent to those who have closely observed lightning that some of the prolonged discharges are in the nature of low currents sustained in some instances in the order of one second. In analyzing the fusion effects account must furthermore be taken of multiple lightning strokes.

Tests made on aluminum sheets will illustrate the distinct character of the surface fusion produced respectively by the intense current of short duration and by the moderate current components sustained for a much longer time. Currents of 125,000 amperes having a total duration of some 400 microseconds produced surface burning concentrated in a $^{1}/_{8}$-inch diameter circle quite similar to those in figure 1. It is estimated that the metal was fused in the test about 0.005 inch below the surface. Tests made on a 0.035-inch aluminum sheet with a 330-ampere current of 108,000-microsecond duration (interrupted in $6^{1}/_{2}$ cycles) burned a $^{1}/_{8}$-inch diameter hole practically through the sheet. In addition four smaller spots were fused in the sheet.

**E. H. Bancker** (General Electric Company, Schenectady, N. Y.): There are several items in Mr. Draper's paper that strike me as worthy of comment. The first of these is the great amount of careful preliminary engineering which was done in connection with the transmission line problem for this project. Under the heading "Specifications" Mr. Draper gives an operating time for the protective system that was written into the specifications, without any statement of how and why these figures were reached. It seems to me that it might interest many of you to know that if a relay system having these characteristics had not been available, it would have been necessary to have constructed a third transmission line to carry the same amount of power through short circuits with maintained stability. This is probably an extreme case illustrating the economic benefits that may result from improved relaying. By the expenditure

of a few thousand dollars in relay equipment, the cost of a several million dollar transmission line was deferred until a higher load condition was reached.

The second item of interest is the statement under "Specifications" that the protection should be immune to operation on an out-of-step or surging condition. Under ordinary circumstances the balanced current relaying will do most of the fault clearing, but obviously each section must have some form of single-line relaying. It may not be appreciated that in this instance, the ability to refrain from tripping is a most important requirement for the single-line relaying. If this were to trip on the power swings following the operation of the balanced relays, the tie between the Boulder Plant and Los Angeles would be lost. This requirement ruled out as back-up protection for single-line operation even such simple things as time-over-current relays, because even they would notch closed on successive power swings. It is rather curious, therefore, that the principal requirement of part of the protective relaying system is not that it shall trip, but that it shall refrain from tripping. This was a performance not obtainable with any other kind of relays, except pilot protection.

The chief item of interest to me in this paper is the operating experience. It is in actual operation that the little unexpected kinks and wrinkles develop and must be ironed out. The experience with the tubes is not unusual, but merely confirms that of other utilities having carrier equipment. Some of the other experiences were rather novel, particularly the operation of the ground relays when a section of line was picked up by closing an oil circuit breaker. Every one knows that the three poles of a circuit breaker do not close at exactly the same instant, but with types of relaying in service and at voltages previously used, the effect of the non-simultaneous pole closing was not noticed in any relay action. In this case the unusually high voltage and length of the line section resulted in a residual current that was big enough, lasted long enough, and was in the right direction to cause the ground relay to operate to trip. The solution of bypassing the high frequency that resulted from these switching operations around the tripping relay coil is merely another example of the high order of engineering that has gone into the design and maintenance of the equipment on the Boulder line.

The methods devised for synchronizing the oscillographs at two stations and tying them in with the closing of a circuit breaker was most ingenious and highly effective. I have seen a number of the records taken in this way and can vouch for the success in recording a large number of electrical quantities at widely separated points with a high enough oscillograph film speed so that individual cycles can be studied and accurate time records of the performance of different parts of the equipment made.

Another interesting item is the use of copper-oxide rectifiers as check valves in trip circuits. As Mr. Draper says, this is probably the first practical use that has been made of this scheme. While it may seem a little thing, again it has considerable economic importance because it permits energizing the circuit breaker trip coils without the wasted time needed to operate an auxiliary relay which would partially undo the good accomplished through the purchase of three-cycle circuit breakers.

In conclusion, I should like to acknowledge publicly the fine spirit of co-operation exhibited by Mr. Draper and his associates during the investigation and correction of the troubles mentioned under "Operating Experience." When users and manufacturers work together with such a fine mutual understanding of each other's problems an amicable and satisfactory solution is reached quickly and easily.

**R. W. Sorensen** (California Institute of Technology, Pasadena): These papers, together with certain other papers included in the symposium, present to the Institute membership the results of almost two years of operation of the present world's outstanding supervoltage power line. The data as presented again exemplify the mastery of electrical phenomena which competent electrical engineers have. In spite of many unusual storm conditions and new features involved in this line, the engineers who planned, designed, erected, and operated it have so completely analyzed all the problems involved and so well anticipated transient outages which have occurred as to make possible this first two years of operation without any very serious interference with the power supply for a great community of people.

When we stop to consider the fact that coupled with all the features of engineering which have been named there was also a change of frequency program involving a change from 50 cycles to 60 cycles for the entire system, we certainly would be remiss if we did not compliment the Bureau of Water and Power staff on its outstanding achievement. In reciting this well-earned tribute we must not fail to note the courage shown by these men in going to a voltage of 287.5 kv when, without additional expense or probably at even less expense, the same amount of power could have been transmitted over 230-kv lines, the construction and operation of which has become more or less standardized.

The lightning protection for the line and the way it has functioned has been so complete and satisfactory that there are few points leading to any discussion. It is interesting to note that a considerable portion of this line—although we generally consider California a nonlightning country—passes through a territory subject to lightning storms, the number of which approximates the average number occurring in many parts of the United States. Indeed the data presented indicate that the severity of these storms is rather high and it would be difficult to overestimate the thoroughness with which Peterson and Cozzens have analyzed the lightning problems and the effectiveness of the measures for guarding against lightning outages which they have included in their line design.

The corona experience on the Boulder Dam line as discussed presents some interesting features in showing a difference between corona loss values as made on sections of line crossing the desert areas and the preconstruction corona loss measurements made in the Ryan Laboratory. Without doubt both sets of measurements are correct and we have before us the striking situation of an increased corona loss in desert areas over that anticipated. I do not think any unexpected corona loss has ever been noticed on the considerable number of miles of 230-kv lines which for years have operated in similar desert areas. There is a possibility that certain sections of the 230-kv lines which traverse desert areas to some extent might show corona loss over that found in nondesert areas, which simply has not been observed because, as the authors have pointed out, the measurement of corona loss on an actual transmission line traversing many kinds of country at different altitudes is no easy matter and none of the lines—the one under discussion or the 230-kv lines which I have in mind—has any great amount of kilowatt-hour corona loss. On the other hand, it may be that the conditions which are essential for the operation of 287.5-kv lines; namely, large diameter conductor and this higher voltage, introduce factors which are not so noticeable at 230 kv and hence do not demand the attention at 230 kv which must be given them at perhaps 287.5 kv and higher—should we in the future raise our transmission voltages to some higher value.

It is interesting to comment here that 10 years elapsed between the installation of 150-kv lines and 230-kv lines—the maximum potential up to the installation of the 287.5-kv lines—and that 15 years have elapsed since the 230-kv lines went into operation; and now we have 287.5-kv lines.

To return to the unexpected excess corona loss on the desert, I will just present for our consideration a report of my observations concerning corona phenomena which may be noted any time in the high-voltage laboratory at the California Institute of Technology. We have installed in the laboratory a smooth bus $3^1/_8$ inches in diameter. With voltages approaching 300 kv applied to this bus, we note that while the complete bus does not go into corona, trees or brushes of corona and sometimes quite definite brush discharges will be noted at points along the bus. These discharges seem to start at places of very slight irregularity or dust accumulation on the bus, even though we sometimes think we have the bus all clean. The difficulty of keeping the bus free from these discharges has led us in our laboratory experiments to use for most of our conductor pieces of chain such as are used for window weights, door checks, etc. Naturally these pieces of chain go into considerable corona at voltages much lower than the initial corona on the $3^1/_8$-inch bus. The corona formed along the chain, however, soon builds up an ionized layer of air around the chain which serves as a shield around the chain and seemingly holds the total corona loss to an amount no more troublesome than the corona which forms on the large bus. In fact, the corona along the chain seems to be limited almost entirely to regular corona glow rather than the brush discharges which occur on the bus. We have never gotten sufficiently interested in the phenomena thus observed to make any measurements. These phenomena, however, in connection with the unexpected phenomena mentioned in the

paper lead me to suspect that small irregularities on large conductors, particularly smooth-surfaced ones, may result under some conditions in corona phenomena quite annoying and difficult to eliminate. Whereas the 230-kv lines which have come under my observation, and which are all stranded-conductor lines, as I have stated, have never shown this phenomenon on the desert to an extent which has led us to believe there is any difference in corona loss on the desert and in the laboratory which cannot be accounted for by the usual things which affect corona; namely, humidity, temperature, barometric pressure, conductor surface irregularity, etc.

**Bradley Cozzens:** The discussions presented by K. B. McEachron and P. L. Bellaschi always add new or confirming facts to any paper because of the very intimate and continuing contact that these men have with lightning studies and associated phenomena. Specifically referring to Mr. McEachron's comments: we too, are pleased to have data indicating that the magnitude of current and possibly voltage encountered in western lightning is not materially different from that of eastern lightning, for it was upon much of the data gathered regarding eastern storms that the lightning design of the Boulder Dam lines was based. From what observation we have been able to make in the few years of construction and operation it appears that the number of strokes per storm may be materially less than for the eastern locations, possibly due to the higher average cloud height and also the smaller amount of actual water vapor involved in any one average storm.

As mentioned in the paper, surge impedance values can be calculated that show a wide variation in magnitude depending upon assumed conditions. We agree heartily with Mr. McEachron in his criticism of the use of a lightning stroke as being a path of definite surge impedance short-circuiting the condenser between the cloud and earth. It is indeed a much more complex circuit. The use of the 200-ohm value, however, gives a design that will cope with some of the most severe lightning strokes while the higher values would of course be more representative of the less intense discharges. Perhaps with further accumulation of information Mr. McEachron or Mr. Bewley, on whom we lean quite heavily for methods of computing lightning phenomena, may evolve methods that will take into account the resistance or impedances between the various charge masses in the cloud to account for the relatively slow build up of the current in the streamers. Such information might modify greatly the present methods of computation, but while we realize that present methods are not rigorous, they are still the only methods available to most of us.

Mr. McEachron mentions that the maximum current is dependent upon the availability of the charge on the ground. The use of the counterpoise makes this charge easily available from a much larger area than normally. It is still questionable whether an extensive counterpoise system may not some day feed such heavy currents into the lightning strokes that the voltage drop in and immediately adjacent to the tower will become a factor. This would be first evidenced on the lower voltage lines.

It is indeed gratifying to have definite confirmation of the formation of corona around the buried counterpoise wires. Our only information, other than reported reductions in measured surge impedance with the application of high surge voltages, was the observed phenomena of corona forming about a conductor in salt water when surged with high impulse voltages. This corona area around the counterpoise was used in the design computations and with Mr. McEachron's comments we are more certain of its justification.

While we had no oscillographic records of the duration of any of the lightning strokes to the Boulder Dam lines, yet mention is made in the paper that from the types of burns observed on the counterpoise gaps, some were probably of short duration while others must have been the result of long-time low-current discharges or many multiple strokes occurring in rapid succession. Mr. McEachron's recently recorded data on the long-time low-current strokes confirms the assumptions mentioned in the paper. Knowing this now to be the case, the information from the counterpoise gaps will be much more valuable for from observing many of them it is possible by careful observation to detect multiple discharges, with appreciable time interval between them by the overlapping of the burned areas. The single-discharge high-current value can be detected relatively easily, and the long-time low-current value also can be identified. Of course these are not instrument measurements and should not be treated as such, but they will add information I feel sure.

Mr. McEachron's comment on the impossibility of a multiple stroke to follow the same general path and travel the 265 feet between tower lines in his maximum observed time of 1.53 seconds is of course correct. However, the change of path for the lower portion of strokes does not seem to be quite as uncommon as indicated. A very beautiful example is given in the United States Department of Commerce Bureau of Standards publication No. 95 on protection of electrical circuits and equipment against lightning. Figures 1 and 2 show the still and moving film records of a multiple stroke in which the lower section entirely changed path for one or possibly more of the discharges. Again we have no definite proof that this was the case for the strokes involving both of the Boulder lines, but as mentioned previously, the desert storms are usually high clouds and are moving rapidly so that successive discharges usually progress with the storm except where the storm clouds are being blown over a mountain area. It is felt, therefore, that strokes to both circuits in a single area come either as this diverted multiple discharge or within a very short time interval.

We greatly appreciate Mr. McEachron's comments on this paper.

The comments of Mr. Bellaschi add further evidence by laboratory tests indicating that burns that result in appreciable fusion of the metal must be the result of long-time low- or moderate-current discharges. The few values mentioned by Mr. Bellaschi covering some of his recent tests indicate that the study of the area and volume of burned metal as a function of the current and time involved is just begun if it is to be used extensively as an indication of lightning current. It, definitely, is a rough means of indication if not interpreted too rigorously.

**J. D. Laughlin:** Discussions and questions as asked by Abe Tilles bring out points and information additional to that contained in the original paper, as the reader may see the subject from a different angle to that presented by the writer.

The following discussion, in answer to Mr. Tilles' questions relative to starting generators at Boulder and energizing the Boulder transmission line and his questions relative to the consequences of tube failures in the supervisory control equipment, gives some additional information pertaining to the operation of the transmission line not included in the original papers.

Starting a generator from the condition with the butterfly valve closed and all auxiliaries shut down normally requires approximately 15 minutes to put the unit on the line. Ten minutes of this time is used in opening the butterfly valve and checking the generator auxiliaries. Before starting any unit, all auxiliaries are operated manually, then shut down and set for automatic operation. Included in the auxiliary check are devices for supplying bearing oil pressure, governor oil pressure, generator cooling water and transformer cooling water, generator field breaker, overspeed devices, and position of the butterfly valve. When these checks are completed and reported to the operator in the control room, he closes the master starting switch. Within two minutes all auxiliaries have been started automatically and the generator is up to full speed. The operator then adjusts the generator voltage and selects the oil circuit breaker to be used for synchronizing. Actual synchronizing and closing of the circuit breaker is done automatically. From the time the generator is up to full speed until it is on the line requires approximately two minutes. If the butterfly valve is open and the scroll case is full of water and it is desired to get a machine on the line quickly, this can be accomplished in approximately four minutes by omitting the auxiliary inspection.

The generators are always synchronized to the lines, using oil circuit breakers on the generator busses. Automatic synchronizing equipment is used for putting all machines on the line for normal operations. Manual synchronizing is used only on special occasions, as for tests or when some equipment is out of service.

When both circuits are de-energized and it is desired to connect Boulder to the system at Los Angeles, two generators are synchronized on the low voltage bus and adjusted for one-third normal voltage. The line is then picked up, one 90-mile section at a time without any further adjustment of the generator fields. When all six sections are energized but not connected to the system, the generator voltage at Boulder is approximately 75 per cent of normal, and at the Los Angeles end of the line the voltage is 100 per cent of normal. The line is then synchronized with the system at Los Angeles. The synchronous condensers for voltage regulation at Los Angeles are connected to transformer banks fed from the 132-kv bus and may be put on the

system either before or after the Boulder line.

A second method has been used for picking up the lines but it is more hazardous to equipment than the one described above. For this method, all circuit breakers on the lines are closed except those that connect the lines to the system at Los Angeles. Two generators are brought up to normal speed and connected to the lines without any field excitation. The generator fields are then closed and excitation is increased slowly until normal voltage is obtained at the Los Angeles end of the line. This method is not used due to the difficulty in regulating generator excitation so as to maintain synchronizing current between the machines and not get the line voltage too high. If one circuit is energized and one de-energized, and it is desired to put the second circuit into service, at least two generators must be on the line at Boulder. The dead line is then picked up one section at a time starting from the Boulder end.

Regarding the failure of tubes in the supervisory control equipment, the most serious result that could occur from a tube failure would be a failure of a nature that would overload and damage other equipment in the carrier-current circuits, such as condensers, transformers, or wiring; however, the circuits are protected with fuses in such a manner that this condition is very improbable. Usually when a tube burns out it stops the transmission or reception of a code and prevents the completion of the intended operation. In no case could it cause a false operation. When such a condition occurs, it is immediately detected at Boulder. The operator can usually determine at which station the failure occurred by noting at what point in the code sequence the equipment stops. He then calls the attendant at the station in trouble by telephone and has him check his equipment. The replacement of a faulty tube is a matter of a few minutes after it fails. The failure of a tube in any station except at Boulder does not interfere with the operation of the balance of the supervisory control equipment. Operations can still be performed at the other stations, and indications received. In case of a tube failure at Boulder, the entire equipment is out of service, since codes from all other stations must be recorded and checked at Boulder before the intended operations can be completed.

**L. L. Draper:** I would like to express my appreciation for the very generous comments of Mr. Tilles and Mr. Bancker on this paper and will endeavor to answer Mr. Tilles' questions regarding the relays in a general discussion rather than trying to answer each question individually.

Each section of the third circuit will be equipped with carrier-current pilot protection like that in use on the present circuits. With this type of protection each section of each circuit is protected as an individual unit and the worst possible condition that the failure of carrier to be transmitted or received can produce is faulty tripping of that particular section upon the occurrence of a through fault condition. As mentioned in the paper the carrier-current pilot protection used is considerably faster than was anticipated at the time the specifications were written and is sufficiently fast to meet the required clearing time under all conditions without any additional speeding up.

As Mr. Tilles has stated complications arise in a scheme of high-speed balance current protection for three parallel lines. This is particularly true with the ring arrangement of six oil circuit breakers as will be used at Boulder, Silver Lake, and Victorville. For this reason and also because balance current protection cannot be applied to the section of the third circuit between Victorville and Los Angeles consideration is being given at this time to other types of protection that might be used as a second line of defense on these lines. The final decision as to the second set of protection equipment on these lines will be to use the overall scheme that will give the least probability of an undesired separation between Boulder power plant and the Los Angeles system due either to failure of the relays to trip a faulted line section or faulty operation of the relays on line sections that are not faulted.

Mr. Bancker has brought out the principle reason for the short operating time requirements of the specifications in so far as this line is concerned, however, there are other well-known benefits to be gained by fast clearing of faults one of which was very well illustrated by the system load dispatchers report of the two faults that occurred on these lines on March 2, 1938. In each case the report contained the very terse statement "No disturbance to voltage." Actually of course there was a disturbance to the system voltage, but of such short duration that from all practical standpoints the statement was absolutely correct.

Mr. Bancker attributes the high-frequency transient currents, that caused trouble with the ground relays, to the nonsimultaneous closure of the oil circuit breaker poles and while this was probably a contributing factor, I believe that the predominating factor in the production of these high-frequency currents was the point on the voltage wave at which individual poles of the breaker closed and that they would be produced on these lines, even with simultaneous closure of the breaker poles.

**Wm. S. Peterson:** The engineers who have been associated with the Boulder Dam transmission line development deeply appreciate the interest shown in this project and are sincerely grateful for the many fine comments that have been made in discussing this group of papers.

In reply to Mr. Tilles' question regarding the alteration of sending-end voltage as the load varies, it can be stated that the operation is very closely in accord with operating under the condition for minimum loss. The normal voltage of the generator is 16,500 volts to produce 287,500 volts at the sending end of the line. This voltage is used when delivering approximately 200,000 kw at the receiving end of the two circuits. For delivering the rated output the voltage is increased to 17,000 volts and for very light loads, under 75,000 kw, the voltage may be reduced to 15,500 volts. This change is made by manual adjustment of the regulator settings. This type of operation requires slightly less synchronous-condenser capacity than does fixed-voltage operation.

Mr. Tilles asks about the location of the third circuit. For two-thirds of the way, it is parallel to the existing circuits and is about 265 feet from such circuits. From Victorville to the Department's receiving station *E*, the line diverges from the existing line going directly west instead of southwest.

Doctor R. W. Sorensen has made the statement that the same amount of power could have been transmitted, without additional expense, at 220 kv.

In such comparisons account must be taken of the type of service, or the conditions, on which the line is rated. Two 220-kv circuits of similar length if operated within the criteria set up for a steady-state stability basis of operation would have about the same rating as do the two 287.5-kv circuits on a transient stability basis. However it was the purpose in building this line to achieve a reliability of transmission equivalent to that given by a local steam-electric generating station. It therefore had to be rated on a transient stability basis for withstanding, without loss of synchronism, a two-phase-to-ground fault at the worst point on the system, drop a section of line and still have a margin of 25 per cent as a safety factor. Calculations show, that, in order to achieve the same rating with 220 kv, it would require the use of three circuits. Three circuits of 220 kv of a given standard of construction are more expensive than two circuits of 275 kv of a similar standard. Economy in obtaining reliability dictated the choice of 275 kv.

Turning to the corona discussion by Doctor Sorensen, I am inclined to agree with his observation that it may not have been observed because measurement of loss on actual lines is difficult to make and it takes accurate measurements to determine the differences under discussion. The phenomena has been identified as having relation to locality, so it is possible that other lines are in areas not affected by the same factors as are present in some places along the Boulder lines.

In making the corona-loss measurements at Victorville the voltages for the conductors under test were carried as low as 220 kv. For these low voltages, the "voltage shifts" in the corona-loss curves for the desert area from those run at Stanford on the same conductors are of the same order of magnitude as found at the higher portion of the loss curves. These measurements were on conductors having diameters of 1.25 and 1.4 inches for the smooth surface type and 1.4-inch diameter for the stranded type. It is reasonable to suggest that if the smaller diameter conductors associated with 220-kv lines had been tested at the same location that a similar shift would have been found and that it would have given appreciable loss differences because 220 kv would have been nearer the "knee of the curve" for such conductors than those tested.

# The Electric Strength of Air at High Pressure

By H. H. SKILLING
MEMBER AIEE

**Synopsis:** Experimental data show that the strength of compressed air as an insulator increases with pressure until a critical value is exceeded. At higher pressures the sparking voltage fails to rise, and may even drop. The maximum voltage and the critical pressure are largely dependent on the shape of the electrodes of the spark gap.

OVER thirty years ago work was done by Ryan[1,2,4] and his student, Ekern,[3] to determine the electrical strength of air at pressures of many atmospheres. It was discovered that the voltage required for sparking between points bears a roughly linear relation to the air pressure until the voltage has risen to approximately ten times that required for sparking between the same points, at the same spacing, at normal atmospheric pressure. A maximum voltage is reached at an air pressure of between 100 and 200 pounds per square inch. As the pressure is further raised, the sparking voltage does not rise correspondingly—in fact it drops somewhat if sharp points are used, and then at still higher pressure (above 400 pounds per square inch) the voltage rises slowly with pressure.

More recent work has been done by a number of scientists: some of this work is summarized by Whitehead.[11] The latest to be published is by Goldman[12,13] of the Union of Socialist Soviet Republics. Goldman's work will be mentioned again in a later paragraph.

Renewed interest in the electrical properties of air at high pressure has appeared recently. This may be traced to the present use of compressed gas as insulation in radio transmitter condensers, in electrostatic generators, and its proposed use in high-voltage power cables. The present paper is a report of an experimental study of the subject.

The chief contribution of the present paper is a study of the effect of the shape and material of electrodes. In previous investigations Ryan and Goldman worked with points, and Goldman, Amyashi, and others, worked with plane surfaces or surfaces with large radius of curvature. It is believed that no one has heretofore investigated both of these types of electrodes and also the intermediate region of electrodes of various radii of curvature. In the investigation of electrode material, electrodes of copper, iron, and zinc were used.

The present investigation also gives assurance that the results are not seriously influenced by distortion of the electric field, brought about by proximity of the walls of the enclosing chamber. Previous work has been done in pressure chambers of relatively small size.

## Apparatus

The pressure chamber in the present work has an inside diameter of six inches. This permits the study of longer gaps and larger electrodes than were used by Ryan, including electrodes of spherical and cylindrical form. However, the increased diameter of the test chamber makes it advisable to use a relatively low maximum air pressure, and since the most essential and characteristic sections of Ryan's curves appeared at pressures below 300 pounds per square inch, the present apparatus was designed for that pressure. Glass and porcelain insulation is used, and voltages lie in the same range as that studied by Ryan.

The outside of the air pressure chamber is shown in figure 1. Two sections of six-inch steel pipe are separated by a sheet of glass, and the cylinder thus formed is closed with a six-inch extra-heavy cast-iron blind flange at each end. The sheet of glass is 14 inches square, with a four-inch round hole in the center. This cylinder, with the insulating sheet of glass and the two blind flanges, occupies a central position in figure 1; it is the test chamber, and air is pumped into it through a pipe inserted in the lower flange.

The cylinder is made to retain air under pressure by being clamped between a pair of eight-inch I-beams, as shown in figure 1. Just above the pressure cylinder is seen a cast-iron spacer block, and between that and the upper beam is a small steel roller for equalizing forces. By tightening screws beneath the standard suspension-insulator units at the ends of the beams, the beams are drawn together. This exerts an axial force on the cylinder, and a compressive force on the glass of about 10,000 pounds. The insulator units, together with the glass sheet, completely insulate the upper beam and the upper half of the cylinder from the lower beam and the lower half of the cylinder. Leads from a high-voltage transformer are connected to the two beams.

Within the pressure chamber is the small frame shown in figure 2. The vertical members of the rectangular frame are insulating, and electrical connection is provided from the top and bottom of the frame to the upper and lower blind flanges, respectively. Some of the electrodes used appear in the photograph. Sharp points, spheres, and cylinders were used, of different materials, and with various sizes and spacings.

Sixty-cycle alternating voltage was used in all tests. A 300-kv, 150-kva transformer was used to supply the test voltage. Power was supplied to the transformer from either the sine-wave generators of the Ryan Laboratory or the commercial supply mains; even in the latter case the wave form does not vary from a sinusoidal wave by a significant amount. Voltage was adjusted by variation of the generator field (when the generator was used) and by means of an induction voltage-regulator in the transformer primary circuit. The voltage was measured by means of a tertiary voltmeter winding, known to be correct.

The location of the spark within the chamber, and the relative intensity of the spark, could be observed through the insulating glass sheet. In this way it was known that the spark occurred between electrodes, as desired. In one test the spark took place, due to moisture, along the surface of the glass within the apparatus; this was immediately detected and corrected. It was not possible, however, to see anything of the form or nature of the discharge.

## Results

Experimental results are plotted in figures 3, 4, 5, and 6. These curves indi-

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1. For all numbered references, see list at end of paper.

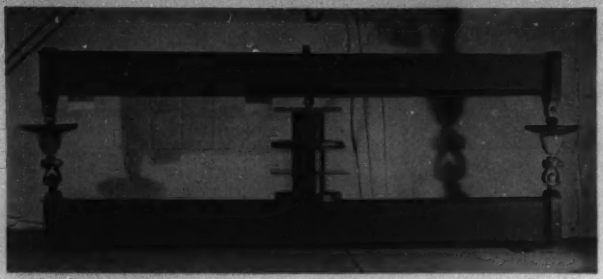

**Figure 1. The test chamber for holding compressed air**

cate average sparking values, each measurement being repeated five to ten times. As an indication of the consistency of results it may be well to consider a sample of the work in detail. Curve *A* of figure 5 is drawn through a number of small circles which represent the average experimental points. At each pressure used the sparking voltage was measured some five or ten times, and the average value is marked by the circle. Individual measurements of voltage were likely to vary by as much as ten per cent; for example, the point on curve *A* at 290 pounds per square inch pressure represents an average of eleven voltage readings that varied from 37.8 to 41.0 kv. Despite this variation of individual measurements, the average values are consistent and reproducible from time to time.

When the electrodes are sharp points, as in figure 3, a maximum value of voltage is evident at about 100 pounds pressure. As pressure is increased from 100 to 150 pounds, voltage for sparking declines. At higher pressure the voltage may or may not rise again, depending on sharpness of the points; at pressures above 100 pounds the voltage required for sparking is greatly increased by dullness of the points (see figure 6). These results are similar to those obtained by Ryan;[2] Goldman,[11] producing sparks between a pointed electrode and a plane, gives voltage-pressure curves of the same shape but with 30 to 50 per cent lower voltage values.

Sparking voltage values in the high-pressure range are erratic compared to sparking voltages at pressures below 100 pounds. This suggests a different mechanism of spark formation. Also, in the higher pressure range there were almost invariably, discharges between electrodes at voltages five to ten per cent below the "sparking voltage" plotted in the curves. These preliminary discharges were of momentary duration, and failed to initiate a complete breakdown of the gap. (They sometimes carried enough current to actuate a circuit-breaker in the primary circuit of the high-voltage transformer, so that it chattered but did not trip. The plotted "sparking voltage" is the voltage at which the breaker opened. The height of the curves obtained would vary a few per cent with changes of the speed and setting of the breaker. Therefore, for consistent results, the setting was kept always the same.)

In figure 4 are shown curves of sparking voltage for one-inch-diameter spherical electrodes (steel balls from a ball bearing). Considering the spacings used these are large spheres, and the electric field between them in the region of nearest approach is almost uniform. (The maximum field strength is increased three per cent by curvature of the spheres.) Since the electric field near a sharp point is highly divergent, the pointed and spherical electrodes represent opposite extremes of electrode configuration.

It will be seen from figure 4 that between spherical electrodes the sparking voltage increases with pressure in a more or less linear fashion until a pressure of about 250 pounds is reached. At higher pressures the sparking voltage remains constant, within the experimental range. The effect of pressure above 300 pounds on the sparking voltage could not be determined because of limitations of the apparatus. Other investigators[1,11,13] show similar flattening of the voltage-pressure curve, but at higher values of voltage and pressure. Although all investigators show the flattening effect, there is little agreement as to the voltage and pressure at which it occurs. There is the possibility that the flattening of the curves of figure 5 is merely a point of inflection, and that voltage would again rise with large increase of pressure. The author, interpreting sparking at high pressure as due to field current, believes that different investigations give different results because of unlike conditions of electrode surfaces. The importance of this factor will be considered later.

Figure 5 shows the gradual change of form of the voltage-pressure curve as the radius of curvature of the electrodes was reduced. All of the curves of that figure apply to spark gaps of 0.05-inch length. Curve *A* was obtained with large steel spheres ("large" in the sense that the radius was nearly ten times the gap length). The practically identical curve *B* is for cylindrical zinc surfaces with large radius of curvature. Curve *C*, for small steel spheres, with radius approximately equal to the spacing between them, is noticeably different; and curve *D*, obtained with electrodes of copper wire spaced nearly twice their radius, shows further difference of the same nature. As the radius of curvature is decreased the curves are less sharply flattened at 250 to 300 pounds pressure, and the voltage required for sparking in that pressure range is reduced. Curve *E*, for a smaller iron wire, and curve *F* for a smaller copper wire, are further altered in the same manner. Curve *G* represents two sets of data that were practically identical: they were obtained with electrodes of copper wire in one case, and with blunt steel points in the other. The radius of the copper wire was $^1/_{10}$th the gap length (0.010-inch diameter); the steel points as viewed under a microscope were rounded at the tips due to the original sharp point having been burned to a blunt end about 0.015 inch across.

The same dull points were used for one of the curves of figure 6; the spacing between them having been increased to 0.30 inch. The two other curves of that figure correspond to increased sharpness of the same points, the "sharp" points being freshly ground and showing, under the microscope, the marks of the abrasive wheel. These three curves continue, in a sense, the series of curves of figure 5, for they complete the transition from "large" spheres to sharp points. Through the entire series the voltage maximum at about 250 pounds pressure becomes less apparent, and a maximum at about 100 pounds pressure appears as characteristic of sharp points. Curve *G* of figure 5 is the first to show a pronounced hump in the 100-pound region.

The various electrodes used for obtaining the curves of figures 4 and 5 are of such simple geometrical shape that the surface electric gradient corresponding to breakdown could be computed. (The electrodes for curve *G*, however, were

omitted because corona probably produces space charge about them before sparking voltage is reached.) The maximum surface gradients obtained, corresponding to the flattened parts of the curves at high air pressures, are as follows:

| | Maximum Gradient for Sparking (Crest Kilovolts per Centimeter) |
|---|---|
| Gap length 0.05-inch between: | |
| Steel spheres, 1-inch diameter | 450 |
| Steel spheres, 0.125-inch diameter | 540 |
| Copper wires, 0.063-inch diameter | 510 |
| Iron wires, 0.041-inch diameter | 470 |
| Copper wires, 0.025-inch diameter | 530 |
| Zinc, radius of curvature 0.5 inch | 450 |
| Gap length 0.017 inch between: | |
| Steel spheres, 1-inch diameter | 550 |
| Gap length 0.075 inch between: | |
| Steel spheres, 1-inch diameter | 450 |

Three electrode materials were used. They were copper, iron (and steel), and zinc. Zinc was used because its low work function contrasts with those of copper and iron. Steel and zinc surfaces gave almost indistinguishable voltage-pressure curves. The average of the maximum gradients for copper is a little higher than the average for iron (520 kv per centimeter, compared to 490 kv per centimeter) but this difference is probably not significant. The author's conclusion is that electrode material has little if any effect in the impure state in which it must necessarily exist during electric discharge in compressed air.

## Discussion

A dash line, *H* in figure 5, is drawn to indicate the voltage that would be required for sparking if Paschen's law were valid in this pressure range. Paschen's law expresses breakdown voltage as a function of the product of air density and linear dimensions of the gap,[6] and therefore implies that ionization results from impacts of electrons (or ions) that have been accelerated in the gas.[10] It is seen that the law fails to apply at pressures of several atmospheres, and breaks down utterly at about twenty atmospheres. There can be little doubt that the reason for this anomalous behavior is that a source of ionization which is relatively ineffective at low pressure becomes predominant at high pressure. Moreover, the source of ionization that is predominant at high pressure appears to be nearly or entirely independent of pressure. It seems therefore that sparking at high pressure derives most of its ions or electrons from a source that is independent of the gas in the gap.

Field current, or cold-emission current, is quite commonly found to flow between electrodes in high vacuum when the potential gradient is of the order of magnitude of half a million volts per centimeter.[6,7] Residual gas about the electrodes takes no part in this phenomenon, for the mean free path of electrons in the gas may be many times the gap length. The gradient required for field current is greatly dependent on the surface conditions of the electrodes, the necessary gradient being raised by a factor of two or three or more when the surfaces are polished and de-gassed.

Field current can thus appear between electrodes in vacuum when there is so little gas that it plays no part in the discharge. It seems quite reasonable that field current can also appear between electrodes in high-pressure gas, the gas being so compressed that it takes no part

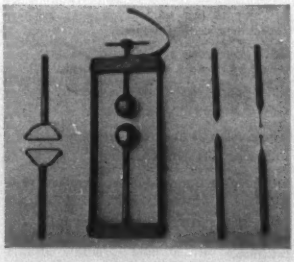

Figure 2. Some of the spark gaps tested

(or only a secondary part) in the discharge. If the mean free path of electrons in the gas is so short that an electron will rarely attain ionizing velocity even though the gradient is raised to the high value required to produce field current, then field current may be expected to flow. This is the most probable cause of the electric breakdown that occurs at high pressure between large, smooth electrodes. It has been so accepted by Ryan and Goldman.

Ryan, in 1911, wrote,[1] "When the stress delivered from the metal electrode surface to the adjacent zone of gas is great enough some of the free electrons in the metal will de detached from the electrode and will migrate through the gas to the anode." Goldman, in 1938, agreed,[13] saying, "Starting from a certain pressure the mechanism of gas puncture is altered. Impact ionization no longer plays a predominant part. With those fields as are obtainable at high voltages, electrons may be torn out from the cathode by the action of the field."

It must be understood that there is no proof that the anomalous sparking voltages at high pressure are due to field current, but there is evidence to support such a belief. The best evidence is that in those cases for which field strength can be computed, the electric field just preceding sparking is of the right order of magnitude to give plentiful field current. Work in vacuum shows (as mentioned above) that an electric gradient of the order of magnitude of 500 kv per centimeter will draw appreciable field current from a metal surface that has not been carefully cleaned, de-gassed, or polished. Compton and Langmuir say,[8] "The past history of the surface has a very great effect on the field strength needed to draw electron currents," and Millikan and Eyring[7] give values varying from 400 to 1,100 kv per centimeter as producing appreciable electron currents from a tungsten filament. Compton and Langmuir found that surface impurities were extremely important, and after saying that "Field currents are obtained much more easily from surfaces covered with adsorbed films of electropositive materials," they report that the result of one test "suggests that traces of alkali metal escaped from the glass and are held by a monatomic oxygen film on the tungsten."

In view of the extreme sensitivity to surface condition it is not surprising that experiments in high-pressure air give breakdown at different values of gradient. It was shown in the preceding table that the gradient believed to produce field current in the present work varied from 450 to 550 kv per centimeter. Goldman obtains a value[13] for a gap of practically the same dimensions, of 730 kv per centimeter in nitrogen, and Amyashi[11] gives data indicating a maximum gradient of about 800 kv per centimeter in both nitrogen and air. All these values are well within the range of gradients determined by work in vacuum. It is evident that when a metallic surface is being subjected to electric discharge in an atmosphere of compressed air it can remain neither highly polished, chemically clean, nor de-gassed. Traces of alkali metals will no doubt always be present. Probably, therefore, the production of field current will depend far more on the presence of unavoidable impurities than on the material of the electrodes. This is consistent with experimental data.

It should be mentioned that it is only in the region of flattening of the pressure-voltage curve that different investigators disagree. When the voltage is less than half that of the flat part of the curve

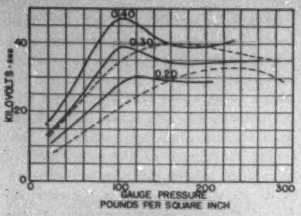


**Figure 3. Sparking voltage between points at various spacings**

Length of gap in inches is marked on curves. Dash lines show Ryan's results for comparison at the two shorter spacings

there is agreement between the present work and that of Goldman and of Amyashi, and between all three and Paschen's law.

The production of electron current by high surface gradient, like the production of electron current by impact ionization, commences gradually and then increases rapidly with increasing applied voltage. Field current in vacuum has been found[8] both theoretically and experimentally to be related to gradient by the equation

$$j = aE^2e^{-D/E}$$

wherein $a$ and $D$ are constants, $j$ is current density, and $E$ is electric field strength. It is evident that field current is negligible at low values of voltage and

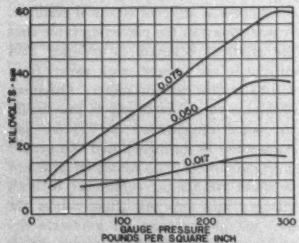


**Figure 4. Sparking voltage between spheres of approximately one-inch diameter, at various spacings**

Length of gap in inches is marked on curves

that, as current becomes appreciable, it increases tremendously with a small increase of voltage.

The electrons of field current, once released into the gas between electrodes in high-pressure experiments, will travel from cathode to anode and will multiply themselves by impact ionization as they go. Even a small supply of field-current electrons will thereby disturb the normal mechanism of sparking in gas, and this may account for the reduction of sparking voltage below that indicated by Paschen's law at intermediate pressures (see, for instance, figure 5). As pressure is increased, and the surface gradient preceding sparking becomes higher, the effect of field current on the spark becomes more pronounced, until finally it is the controlling factor and breakdown voltage is thereafter independent of pressure. The formation of a spark by means of field current probably includes intense heating of a very small spot on the cathode.

## Shape of Electrodes

Experimental data may be considered in four classifications, with indefinite intermediate regions. The four basic categories are:

1*A*. Spark due to ionization of gas; not preceded by corona discharge.

1*B*. Spark due to field current; not preceded by corona discharge.

2*A*. Spark due to ionization of gas; preceded by profuse corona discharge.

2*B*. Spark (see below) preceded by profuse corona discharge.

These classifications correspond to the following physical conditions:

1*A*. Flat or rounded electrodes; low pressure.

1*B*. Flat or rounded electrodes, high pressure, or pointed electrodes in very high pressure.

2*A*. Sharp-pointed electrodes, not close, low pressure.

2*B*. Sharp-pointed electrodes, not close, medium pressure.

Characteristic of classification 1*A* are the curves of figure 4 at pressures below 100 pounds. No explanation is needed, for this type of sparking is that of spheres in open air. These same curves at pressures above 250 pounds illustrate action of type 1*B*: the field strength at the sphere surface rises with increasing voltage until emission of electrons produces field current in sufficient quantity to appear as a spark.

The curves of figure 3, at pressures below 90 pounds, represent sparking of the 2*A* type. This is the customary mechanism of sparking between points in free air.[8] The same curves at pressures of 120 to 150 pounds, and possibly higher, illustrate the 2*B* mechanism of sparking. This requires further consideration.

One is inclined to attribute flattening of the voltage-pressure curves for pointed electrodes, as in figure 3, to the effect of field current emitted from the point. Goldman and Wul's results,[13] however, indicate that such is not the case. Working with direct voltage applied to a gap between one pointed and one plane electrode they found that the typical shape of the a-c voltage-pressure curve (as in figure 3) is reproduced when the pointed electrode is positive, but with the point negative the sparking voltage is higher and continues to rise with pressure through the experimental range (up to 200 pounds pressure). This indicates that the action that causes sparking voltage to diminish as pressure rises must take place at or about the *positive* point, and it clearly cannot be the emission of electrons. Accepting the data of Goldman and Wul, one cannot do better than to accept also their explanation that the anomalous sparking voltage between *points* is due to high concentration of space charge, which, in turn, is the result of low ion mobility in high-pressure gas. This is the 2*B* type of action.

When pressure is further increased the extent of the corona that precedes sparking is curtailed so greatly that the action enters an intermediate region between 2*B* and 1*B*, and at the very high pressures used by Ryan[1] it appears that a

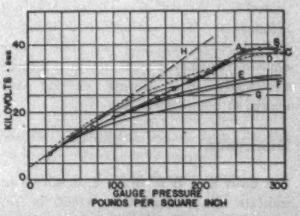


**Figure 5. Sparking voltage between various electrodes, gap length in each case being 0.05 inch**

Electrodes were:

*A*. (Heavy line with circles to indicate average experimental voltage values) Steel spheres, 0.933-inch diameter

*B*. (Dot-dash line, practically coincident with *A*) Zinc cylindrical surfaces, radius of curvature 0.5 inch

*C*. (Light line) Steel spheres, 0.125-inch diameter

*D*. (Dotted line) Copper wires, 0.063-inch diameter

*E*. Iron wires, 0.041-inch diameter

*F*. Copper wires, 0.025-inch diameter

*G*. Copper wires, 0.010-inch diameter, and also points with blunt tips about 0.015 inch across

*H*. Paschen's law (for plane surfaces, extrapolated from low pressure region)

fully 1*B* type of action is attained even between sharp needle points.

The curves of figure 6 show varying degrees of similarity to the typical behaviors 2*A*, 2*B*, and 1*B*. With blunt points the maximum voltage at about 100 pounds pressure tends to disappear, while the maximum at about 300 pounds becomes more prominent.

## Conclusions

1. Sparking voltage in air rises as air pressure is raised above atmospheric, but a maximum value is reached. As pressure is further increased, sparking voltage remains constant or becomes less. Maximum sparking voltage is greater than sparking voltage at atmospheric pressure by a factor of five to ten, depending on the electrode configuration.

2. No difference was observed between iron, copper, and zinc as electrode materials.

3. The form of electrode is very important. Electrodes that permit corona before sparking behave quite differently from those that do not.

4. If there is no corona preceding sparking, maximum voltage is reached at 18 to 20 atmospheres pressure (or higher, according to other investigators).

5. If there is corona preceding sparking a maximum appears in the sparking voltage at 7 to 10 atmospheres pressure, and another maximum appears at 20 atmospheres or higher.

6. Sparking between smooth electrodes at high pressure is probably due to field current; the result, that is, of an electric field so strong that "some of the free electrons in the metal will be detached from the electrode and will migrate through the gas to the anode."

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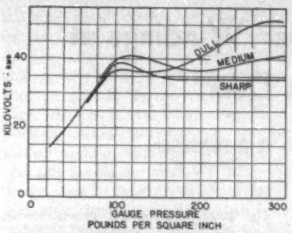


**Figure 6. Sparking voltage between points of various degrees of sharpness**

Gap: 0.30 inch

Dull: rounded tip, about 0.015 inch across
Medium: rounded tip, about 0.005 inch across
Sharp: freshly ground point, less than 0.001 inch across


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## Discussion

**D. W. Ver Planck** (Yale University, New Haven, Conn.): One of the important consequences of Professor Skilling's excellent paper is that it helps to establish a limit for Paschen's law. For instance in figure 5 of the paper, it can be seen that the sparking voltages for substantially uniform field begin to deviate from Paschen's law, curve *H*, at about four or five atmospheres absolute pressure.

In this connection attention should be called to the recent work of Finkelmann published in Germany (*Archiv für Elektrotechnik*, volume 31, 1937, page 282). Finkelmann working with uniform fields and about the same pressure range as Professor Skilling extended his tests to much higher spacings and voltages, and to carbon dioxide, nitrogen, and hydrogen as well as air. His results for air show that the pressure, or more correctly the density, at which deviations from Paschen's law commence increases with the gap length. Thus the limiting pressure increases gradually from Professor Skilling's five atmospheres at a gap of 0.127 centimeter to about eleven or twelve atmospheres at 0.7 centimeter. In the light of Professor Skilling's contention that the deviation is caused by removal of electrons from the cathode by direct action of the electrostatic field (so-called field current), a view also expressed by Finkelmann, it might be better to define the limit of Paschen's law in terms of the potential gradient, the quantity directly causing field current. Doing this one finds that as the gap increases from 0.1 to 0.7 centimeters, the gradient at which the deviations commence is not constant either, but increases from somewhat less than 150 to something over 300 kv maximum per centimeter.

While the data are still too few to finally establish a limiting condition for Paschen's law, its correctness for determining air density correction factors following the method recently given by the writer (AIEE Transactions, January 1938, page 45) and even for extrapolation up to pressures of several atmospheres receives further confirmation from these new researches.

It is unfortunate that Finkelmann terminated his uniform field curves too soon after the deviation from Paschen's law to show the approach to a limiting spark-over voltage at high pressure found by Professor Skilling. Finkelmann does however give results for concentric cylinders which show this phenomenon. For a gap of about 0.9 centimeter in air and a field which is only slightly nonuniform the gradient for the constant spark-over voltage is about 240 kilovolts maximum per centimeter, or only about half that observed by Professor Skilling. On the other hand, some results reported many years ago by Hayashi (*Annales de Physique*, Volume 45, number 4, 1914, page 431) for gaps quite similar in geometry to those of Professor Skilling show very much higher limiting gradients of the order of 1,000 kv maximum per centimeter. These facts are consistent with Professor Skilling's statement that various experimenters do not agree as to the heights of the level portion of the sparking voltage-pressure curves. Evidently determining factors in this phenomenon have not been brought under control.

**H. H. Skilling:** I am in thorough agreement with the discussion by Professor Ver Planck, and particularly wish to emphasize his conclusion that more data are needed. It is, of course, evident that there is room for all the work that has been done at atmospheric pressure to be repeated at many different pressure levels. The present paper is of the nature of a progress report, and it is hoped that further data can be published from time to time as they become available. The author is now extending his work to longer gaps and higher voltages.

In response to an unpublished discussion, it should be mentioned that the usual experimental procedure was to pump air into the test chamber until the pressure was somewhat in excess of 300 pounds per square inch. A valve in the supply line was then closed, and as the temperature of the enclosed air, heated by compression, approached room temperature, the pressure fell to about 300 pounds. After each measurement of sparking voltage, some of the air was released and the valve was again closed; the air was cooled by expansion, but it returned to room temperature in two or three minutes. It was not necessary to wait for room temperature to be reached before testing, as the *density* of the enclosed air could not change; the pressure gauge was read, however, after its indication had reached a steady value.

# Generator Damper Windings at Wilson Dam

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**Synopsis:** The majority of water-wheel generators now in service have been built without damper windings. Recent technical investigations and laboratory tests have indicated that, in addition to reducing oscillations and improving system stability, damper windings are very effective for reducing high-peak voltages during unbalanced short circuits. This applies particularly under switching conditions of clearing a fault when the load is disconnected from the distant end of a transmission line, and the charging current results in capacitive loading of the unfaulted phases. The existence of similar overvoltage conditions was recognized by the Wilson Dam operating staff and later confirmed by oscillograms during tests. This paper summarizes the studies and tests based on the observed overvoltage conditions and describes a method for adding damper windings to large water-wheel generators which are already installed. Short-circuit tests are extended to generators on a large scale which confirm the earlier theoretical and laboratory tests and demonstrate the advantages to be gained by adding damper windings to other water-wheel generators now in service. The tests show that damper windings in one generator when operated in parallel with another generator without dampers are effective in reducing high-peak voltages during unbalanced faults. Data are given to show the changes in machine reactances due to adding damper windings.

FOR many years amortisseur, or damper windings, were included in water-wheel generators only when they were required to meet special conditions such as high starting torque for automatic station service, synchronous condenser operation, or system-stability requirements.

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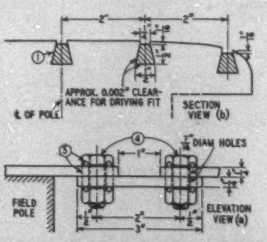
The authors wish to acknowledge the services of the electrical testing laboratory and operating department personnel who made the tests and their assistance in analyzing the results and also the assistance of the Wilson Dam shops in working out some of the details of the winding installation.

1. For all numbered references, see list at end of paper.

The large water-wheel generators at Wilson Dam were installed during 1925 and 1926 without damper windings. The existence of an overvoltage condition during disturbances on an interconnected system was recognized by the Wilson Dam operating staff. At the suggestion of an interconnected company, overfrequency relays were installed for the purpose of disconnecting overspeeding generators although justification of this type of protection was not supported by records obtained from frequency and voltage recorders over a period of several years.




| BILL OF MATERIAL | | FOR ONE GENERATOR |
|---|---|---|
| ITEM | DESCRIPTION | NUMBER REQUIRED |
| 1 | 1/2" x 1/2" x 50 1/2" LONG COPPER BAR | 360 |
| 2 | 1/2" x 1/2" x 12 1/2" LONG COPPER BAR CUT TO FIT | 144 |
| 3 | 1/4" x 1" x 3" LONG COPPER BAR | 144 |
| 4 | 3/8" x 1" HEXAGONAL-HEAD MACHINE BOLT | 288 |
| 5 | 3/8" STEEL KEEPER WASHER | 288 |

It was expected by local plant engineers that the final explanation of this condition would be obtained during other tests with an oscillograph. During the latter part of 1935 a six-element oscillograph was purchased for use by the electrical testing laboratory. During March 1936, staged tests were made to determine certain relay and equipment characteristics. Other tests followed late in the summer. During the first series of tests one phase of a new lightning arrester broke down. This arrester failure together with the results of preliminary tests led to laboratory studies by the manufacturer and the resulting paper by Wagner.[2] The oscillograms indicated that high-peak voltages were present on the unfaulted phase during line-to-line faults on the distant end of a transmission line which had been taken out of service for tests. Peak voltages as high as 343 kv between high-voltage bus and ground were recorded on the unfaulted phase at the sending end of the 154-kv line. Peak voltages of this magnitude are severe on equipment during the duration of an unbalanced fault.

## Technical and Design Features

The generator used for these tests is rated 32,500 kva, 0.8 power factor, 12,000 volts, three-phase, 60 cycles, 100 rpm, vertical axis, and the detailed reactances are given in table III. Staged tests without damper windings were also made on a 25,000-kva generator with other data similar to the above machine except it was built by another manufacturer and similar peak voltages were obtained during these tests.

During conferences and correspondence on the subject, several suggestions were

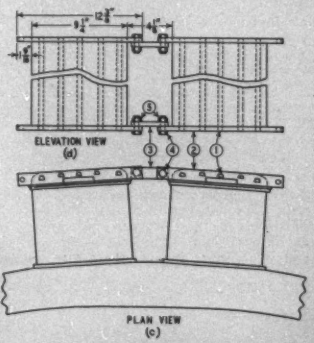



**Figure 1. Sketch showing details of damper winding installation**

(a)—Details of copper connection between adjacent poles

(b)—Section view of field pole showing location and dimensions of slots and damper bars

(c) and (d)—Plan and elevation view assembly sketches

given for the prevention of damage to the equipment due to overvoltage.

1. A set of specially designed spark gaps connected between the high-voltage bus and ground and designed to operate with a few microseconds' delay after the appearance of sustained overvoltage.

2. A combination filter and protective gap connected to the generator leads.

3. The installation of damper windings which would effectively limit the magnitude of unbalanced, distorted phase potentials.

4. Continue the present practice of operating the plant with all generators electrically connected to the same bus, except as required by other system operating conditions. It was also recognized that it was desirable to have other balanced loads particularly synchronous motors or condensers connected to these machines.

The first suggestion was rejected because of operating problems involved together with space requirements and cost. The transformers were already provided with protective gaps. The second suggestion was rejected for substantially the same reasons. Since the effectiveness of the first two suggestions was doubtful for this particular application and would not correct the cause, it was believed that the expense could be used to better advantage in correcting the trouble at its source. The third suggestion for the installation of damper windings was considered the most effective because the machine characteristics directly responsible for the overvoltage condition would be corrected and other benefits of damper windings for improving the stability of rotating machines would be obtained. Both generator manufacturers concurred in recommending the use of damper windings as the best solution for the machines of their own manufacture. Published information on this subject was reviewed and technical investigations were made.

Doherty and Nickle[1] stated that the voltage at short-circuit line to neutral may rise to $(2\ x_q'/x_d') - 1$ times the voltage before short circuit on the open phases. See table III for the identification of $x_q'$ and $x_d'$. This indicated that for a single-phase-to-neutral fault on the generator it was possible to obtain peak voltages 2.65 times the normal voltage across the terminals of the unfaulted phase.

The manufacturer gave some indications of improvement to be obtained by adding damper windings. These values given below represent the ratio of the peak voltage to normal voltage of the unfaulted phase during a line-to-line fault:

| Condition | Generator Only | 20 Per Cent External Reactance |
|---|---|---|
| Continuous damper | | |
| (a) maximum flux | 1.34 | 1.2 |
| (b) minimum flux | 1.17 | 1.1 |
| Discontinuous damper | | |
| (a) maximum flux | 1.84 | 1.5 |
| (b) minimum flux | 1.42 | 1.25 |

This information indicated the expected reduction in peak voltage to be obtained with each type of damper winding.

The paper by Wagner,[2] written after the designs were completed but before the last short-circuit tests, gave some useful information concerning the effect of inductive, pure resistance, induction-motor and capacity loads on the peak voltages, and the effect of damper windings. On page 1389[2] it is also stated that for a terminal-to-terminal fault on an unloaded machine, the crest of the sum of the odd harmonics measured from the sound phase to the short-circuited phases just after short circuit is equal to (3/2) $(x_q''/x_d'')$ times the crest of the normal line-to-neutral voltage for a machine without dampers. For a machine with damper windings the factor is (3/2) $(x_q''/x_d'')$. These reactances can be identified by referring to table III of this paper. If the corresponding values for this generator are used, these formulas would indicate a ratio of 2.54 without dampers and 1.64 with the continuous damper which was added. All of the above-calculated values, unless otherwise indicated, apply to only the generator and are in fair agreement when we consider the state of knowledge of the subject and the differences in assumptions for the equations. Other factors, including the type and location of fault, different external impedances, different transmission-line constants, and the part of the reference-voltage wave at the instant the fault occurs (maximum, minimum, or some intermediate flux condition) should be taken into account, and these result in complicated computations.

During the technical investigations, additional information concerning damper windings and generator characteristics was obtained from published articles by Wagner,[2] Kilgore,[4] Wright,[5] Park and Robertson,[6] Linville,[7] and Wagner and Evans.[8] Clarke, Weygandt, and Concordia[9] have reported some additional information which was not available until our tests were completed.

Preliminary information from the manufacturer suggested the use of five round one-half-inch-diameter copper bars in each pole. This was a good theoretical shape of bar which would result in minimum change in normal field distribution at the surface of the field pole. Round bars are very difficult and expensive to install in the field on account of requiring removal of the laminations from the field pole, possible damage to the field insulation, the cost of making a new die, and requiring a punch press. Round bars can therefore be better installed at the factory.

Figure 2. View showing method of swaging copper bars in slots and welding of bars to segments of short-circuiting copper rings

During the design, such items as the equipment available in the shops and in the plant, the classes of workmen available to perform each operation, features which would require dismantling the machine, if this is not desired for other maintenance work; obstructions to be avoided; available space; provision for performing each operation, such as machining, welding, etc.; mechanical re-

Figure 3. Rotor with field poles and bolted connections between copper segments of adjacent poles nearly completed

**Figure 4. Oscillogram of test number 1**

1. Generator phase-*C*-to-neutral voltage
2. Generator phase-*B*-to-neutral voltage
3. Generator phase-*A*-to-neutral voltage
4. Line phase-*B*-to-neutral voltage
5. Line phase-*A* current
6. Transformer neutral current

quirements and factor of safety during maximum overspeed; electrical, insulation, magnetic, and physical requirements, including thermal expansion, etc., had to be considered.

In order to obtain minimum disturbance to the normal magnetic field at the pole face, the one-quarter-inch minimum width of opening into the slot without excessive cost was determined by experiment in the shop. The bars were designed to have approximately the same cross section as a one-half-inch-diameter copper bar. Sketches of the preliminary design for each of the two ratings of main generators in the plant were submitted to the manufacturer of the corresponding machine for comments. The principal changes which resulted were increasing the cross section of copper links between the copper segments of adjacent poles for electrical conductivity and the use of bolted connections instead of using laminated brush copper links welded to the copper bar at each end. Slots at the bolted connection were considered a better provision for thermal expansion and contraction at this location. Sketches of the completed design for this machine are shown in figure 1.

## Details of the Damper Winding Installation

This generator had been in service approximately 12 years and the insulation was beginning to show signs of brittleness and other indications of deterioration. Special handling was therefore necessary in order to forestall serious damage to the generator parts during the course of alterations. Each field pole was carefully removed by means of a sling and placed on a truck for transportation from the powerhouse to the shops which was a distance of approximately one-quarter mile. A field pole was first mounted on the bed of a large planer in the conventional manner for cutting the slots, but difficulty was experienced in obtaining uniform slots due to the tendency of the planer tool to "dig in." The scheme selected was a modified milling head attached to the cross-feed of the planer. This equipment was designed and built for this particular application. Each of the five slots were cut in three transverses of the milling head. The angle of the cutter and the position of the planer bed holding the pole-piece was changed for each cut resulting in a slot which has the form of an inverted keystone or dovetail. The field pole was clamped securely, and during the cutting operation it was covered to prevent steel chips from dropping between the windings. The accumulation of chips was blown away by an air jet as required.

The keystone-shaped copper bars were inserted in the slots. Figure 2 shows a cradle structure which was used to support the field poles and also shows how the welding and swaging were done. These operations, of course, were not performed at the same time. The electrical bonding at the ends of the bars was done by means of a carbon arc and "silphos" welding rod. Sufficient clearance was provided between the copper cross-connection and the iron laminations to allow for only differential thermal expansion and contraction. An air hammer was used in swaging the bars to make the outer part of the bars fit more firmly in the slots and prevent noise or excessive vibration while in service.

During the progress of the work, a number of tests were made to check the expansion of the bars while carrying heavy 60-cycle alternating currents. Sample welds and mechanical and electrical tests were made, as required, in order to check the suitability of the installation as well as the electrical and mechanical requirements.

Figure 3 shows the field poles nearly all assembled on the rotor. The copper bars which form the electrical connections between the damper bars of adjacent field poles may also be seen near the upper and lower part of each field pole. These bars are bolted together with steel machine bolts and steel keeper washers are used to prevent them from becoming loose. Each part of the generator was marked before dismantling and the parts were reassembled in their original locations.

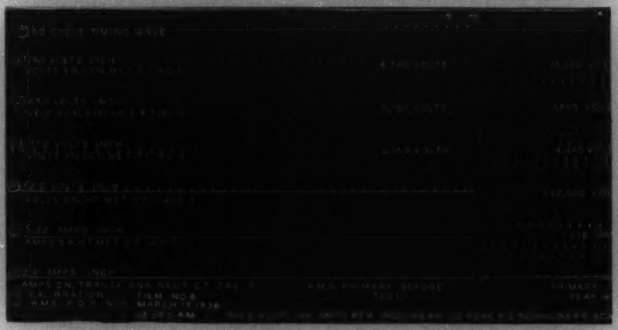


**Figure 5. Oscillogram of test number 2**

*T.* 60-cycle timing wave

1. Generator phase-*C*-to-neutral voltage
2. Generator phase-*B*-to-neutral voltage
3. Generator phase-*A*-to-neutral voltage
4. Line phase-*B*-to-neutral voltage
5. Line phase-*A* current
6. Transformer neutral current

The generator rotor and shaft were realigned on being put back together. All parts were cleaned and the coils were treated with insulating varnish during the course of the work. The machine when finally put back in service was in better operating condition than before this work was started.

## Short-Circuit Tests

After the generator was reassembled, short-circuit tests were made to determine the effectiveness of the damper windings. The test conditions were made to correspond with those during the tests made before the installation of damper windings.

The generator windings are connected in wye with the neutral point grounded through a resistor. The low-voltage side of the power transformer bank is connected in delta and the high-voltage side is connected in wye with the neutral solidly grounded. Potential transformers connected wye–wye to the low-voltage bus made possible the measurement of phase-to-phase, or phase-to-ground potentials. The potential transformers of the high-voltage metering equipment are normally connected open delta and these were reconnected to measure the potential between the unfaulted phase of the high-voltage bus and ground. High-voltage short-circuit currents were measured by means of wound-type current transformers located either in the high-voltage metering assembly or in the circuit between the transformer-bank neutral point and the station ground.

Oscillograph records were made of the fault current and the unfaulted phase-to-ground potential on the high-voltage side and the three phase-to-neutral potentials of the generator. Records of field current and other features were taken during some of the tests.

All of these staged short-circuit tests were made on the Wilson Dam to Centerville section of the Wilson-West Nashville 154-kv line. This section of the line was taken out of service and fault connections were made at Centerville, Tenn., which is 68.36 miles from Wilson Dam. The generator combinations were connected to energize the transformer bank at approximately no-load voltage, and the faults were initiated by closing the high-voltage line breaker. Another high-voltage breaker and the low-voltage bus breakers were used for back-up breakers in case of emergency.

Test numbers 1 to 5, inclusive, in table I were made before damper windings were added. Test numbers 6 to 9, inclusive, were made after damper windings were added to generator number 8. During the comparison of results it was observed that tests 1 and 2 were made with 11,500 rms volts between generator terminals; tests 3, 4, and 5 were made at 11,400 volts and tests 6 to 9, inclusive, were made at 10,700 volts. In order to have all tests on the same basis for comparison, the peak voltage between the low-voltage bus and ground before the fault was applied was used as 100 per cent and compared with the corresponding voltages during the fault. The corresponding peak voltage between the high-voltage bus and ground before the fault was applied was obtained by calculation from the transformer ratio and used as 100 per cent for comparison with peak voltages existing during the tests. The transformer ratio was 10,980 volts delta to 154 kv wye. The maximum peak voltage obtained from the oscillogram after the fault was applied was expressed as a percentage of the corresponding initial peak voltage. These percentages were used as the basis for comparison.

These tests were made with no-load voltage on the generators. The fault currents and also the peak voltages during the fault would be higher if the generators had additional excitation with the generators under load. An approximate estimate of the increased voltage peaks due to additional excitation under load could be obtained by using the generator magnetization curve for the corresponding field current under load conditions and using the ratio of the new voltage to the voltages at which these tests were made. An

**Figure 7. Oscillogram of test number 9**

*T*, 60-cycle timing wave

1. Generator phase-*A*-to-neutral voltage
2. Generator phase-*C*-to-neutral voltage
3. Generator phase-*B*-to-neutral voltage
4. Line phase-*B*-to-neutral voltage
5. Line phase-*A* current
6. Transformer neutral current

**Figure 6. Oscillogram of test number 8**

*T*, 60-cycle timing wave

1. Generator phase-*A*-to-neutral voltage
2. Generator phase-*C*-to-neutral voltage
3. Generator phase-*B*-to-neutral voltage
4. Line phase-*B*-to-neutral voltage
5. Line phase-*A* current
6. Transformer neutral current

**Table I. Summary of Tests**

| Test Number | Conditions | Phase | Low-Voltage Bus Phase to Ground Peak Volts (Kv) | Low-Voltage Bus Phase to Ground Peak Volts (Per Cent) | High-Voltage Line Unfaulted Phase to Ground Peak Volts (Kv) | High-Voltage Line Unfaulted Phase to Ground Peak Volts (Per Cent) | High-Voltage Line Fault Amperes at Nine Cycles (RMS)* |
|---|---|---|---|---|---|---|---|
| 1 | Generators 5 and 6, no reactors, bank 12, phase-*C*-to-*A* fault | *A* | 6.84 | 69.3 | | | 444 |
| | | *B* | 20.3 | 215 | 303 | 227 | |
| | | *C* | 17.84 | 189 | | | |
| 2 | Generator 6 with reactors, bank 12, phase-*C*-to-*A* fault | *A* | 5.48 | 58.3 | | | 236 |
| | | *B* | 17.25 | 183 | 303 | 227 | |
| | | *C* | 14.74 | 156 | | | |
| 3 | Generator 8, regulator in, no reactors, bank 11, phase-*B*-to-*C* fault | *A* | 20.55 | 220.5 | 343 | 361 | |
| | | *B* | 17.88 | 192.0 | | | |
| | | *C* | 5.95 | 63.8 | | | 291 |
| 4 | Generator 8, regulator in, no reactors, bank 11, phase *B*-*C*-ground fault | *A* | 13.27 | 142.2 | 196.5 | 150 | |
| | | *B* | 12.61 | 135.3 | | | |
| | | *C* | 5.95 | 63.8 | | | 251 |
| 5 | Generator 8, regulator in, no reactors, bank 11, phase-*A*-ground fault | *A* | This film | | | | |
| | | *B* | no | | | | |
| | | *C* | good | | 222.2 | 170 | |
| 6 | Generator 8, regulator in, bank 11, no reactors, phase-*A*-to-*C* fault | *A* | 5.4 | 61.8 | | | 211 |
| | | *B* | 11.5 | 131.8 | 206.2 | 166 | |
| | | *C* | 13.63 | 156 | | | |
| 7 | Generators 7 and 8, regulators in, no reactors, bank 11, phase-*A*-*C* fault | *A* | 5.09 | 58.3 | | | 325 |
| | | *B* | 14.0 | 160.3 | 231 | 186 | |
| | | *C* | 14.3 | 164 | | | |
| 8 | Generator 8, regulator in, no reactors, bank 11, phase-*A*-*C*-ground fault | *A* | 3.08 | 35.2 | | | 245 |
| | | *B* | 10.33 | 118.2 | 156.7 | 126.5 | |
| | | *C* | 13.1 | 150 | | | |
| 9 | Generator 8, regulator in, no reactors, bank 11, phase-*A*-ground fault | *A* | 8.79 | 100.5 | | | 304 |
| | | *B* | 9.14 | 104.7 | 148.7 | 119.7 | |
| | | *C* | 13.45 | 154 | | | |

* The current waves are not all perfect sine waves. These root-mean-square currents are therefore approximate.

**Table II. Comparison of Test Results**

| Test Conditions | Bus | Peak Volts Without Dampers Kv (1) | Peak Volts Without Dampers Per Cent (2) | Peak Volts Dampers in One Generator Kv (3) | Peak Volts Dampers in One Generator Per Cent (4) | Maximum Per Cent Volts Decrease With Dampers (5) | Maximum Per Cent Volts Increase Without Dampers (6) |
|---|---|---|---|---|---|---|---|
| Two generators Phase-phase fault | LV | 20.3 | 215 | 14.3 | 164 | 23.7 | 31 |
| | HV | 303 | 227 | 331 | 186 | 18.05 | 22 |
| One generator Phase-phase fault | LV | 20.55 | 220.5 | 13.63 | 156 | 29.2 | 41.3 |
| | HV | 343 | 261 | 206.2 | 166 | 36.4 | 57.2 |
| One generator Phase-phase-ground fault | LV | 13.27 | 142.2 | 13.1 | 150 | 5.5* | 5.2* |
| | HV | 196.5 | 150 | 156.7 | 126.5 | 15.65 | 18.6 |
| One generator Phase-ground fault | LV | Film no good | | 13.45 | 154 | | |
| | HV | 222.2 | 170 | 148.7 | 119.7 | 29.6 | 42 |

NOTE: Designation (LV) above refers to the maximum bus-to-ground peak voltage of the three phases of the low-voltage bus as recorded in table I, Summary of Tests.
(5)—Column (2) minus column (4), expressed as a percentage of column (2).
(6)—Column (2) minus column (4), expressed as a percentage of column (4).
* An increase in voltage at low-voltage bus is indicated, but the high-voltage line shows a reduction.

exact solution would require detailed calculations involving the internal characteristics of the generator.

Figures 4 to 7, inclusive, are oscillograms of test numbers 1, 2, 8, and 9, respectively. The voltage and current values printed on the films of figures 4 and 5 are the magnitudes at nine cycles made during preliminary analyses. The maximum peak voltages used for the comparison of test results are given in table I.

Table I shows the station combinations used for each test, the type of fault, and the resulting peak voltages and per-cent voltages. Generators 5, 6, 7, and 8 are identical machines and the transformer banks are identical.

Table II is a comparison of test results before and after damper windings were added to generator number 8. This table also shows the per-cent increase in peak volts which were obtained before this type of damper winding was added to the generator. The advantages to be gained by adding damper windings to water-wheel generators now in service are self-evident.

Theoretical calculations were not made to determine if a different length of transmission line would result in higher peak voltages. C. F. Wagner[1] has reported that transmission lines having different lengths or different constants will produce harmonics of different magnitude and therefore different peak voltages during unbalanced faults without damper windings in the generator.

## Changes in Generator Reactances

Table III gives the calculated per unit reactances of the generator without damper windings and the corresponding values after damper windings were added. These calculated reactances were obtained from the manufacturer.

## Conclusions

1. The results obtained in the reduction of peak voltages for different types of unbalanced faults are summarized in table II. These percentages may change a slight amount if the faults occurred at different points of the voltage wave of the short-circuited phase, but these tests may be considered as representative of the improvements to be expected.

2. These tests show that one generator with damper windings when operated in parallel with another generator without damper windings is very effective for reducing the peak voltages during unbalanced faults.

3. A close inspection of the open-circuit voltage of the oscillograms in figures 6 and 7 will reveal five very small voltage ripples corresponding to the five damper bars in each pole. These voltage ripples, or harmonics, are too feeble to cause telephone interference and they are not noticeable when the machine is operated in parallel with another generator. These harmonics can be reduced by using round copper bars or reducing the width of the dovetail-shaped copper bars near the surface of the field poles, but it would be more expensive and would result in a more difficult mechanical job of machining the slots for the damper bar installation.

4. Since the direct axis subtransient, negative-sequence, and zero-sequence reactances have been reduced, the fault currents are increased by the addition of damper windings. However, for faults beyond the generator bus the external impedance prevents the fault current from being increased in direct proportion to the reduction in generator reactance. Table I shows the comparative root-mean-square fault currents in the high-voltage line nine cycles after the beginning of the fault.

5. It is believed that the installation of damper windings will solve some of the problems of operating companies who have unexplained voltage surges during system disturbances.

## Bibliography

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Table III

| Per Unit Reactance | | Amortisseur | | Per Cent Reduction |
|---|---|---|---|---|
| | | Without | With | |
| Leakage | $x$ | 0.22 | 0.22 | 0 |
| Direct synchronous | $x_d$ | 1.15 | 1.15 | 0 |
| Quadrature synchronous | $x_q$ | 0.73 | 0.73 | 0 |
| Direct transient | $x_d'$ | 0.40 | 0.40 | 0 |
| Quadrature transient | $x_q'$ | 0.73 | 0.73 | 0 |
| Direct subtransient | $x_d''$ | 0.32 | 0.265 | 17.2 |
| Quadrature subtransient | $x_q''$ | 0.73 | 0.29 | 60.3 |
| Negative sequence | $x_2$ | 0.48 | 0.28 | 41.7 |
| Zero sequence | $x_0$ | 0.14 | 0.123 | 12.13 |


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## Discussion

**H. E. Bussey** (General Electric Company, Atlanta, Ga.): The authors of this paper present in an admirable manner the advantages to be derived by the addition of amortisseur windings to salient-pole generators in the suppression of overvoltages occasioned by short circuits. Great ingenuity is shown in coping with the mechanical problems incident to the installation of amortisseur windings in a generator as large as this, not originally designed for amortisseur windings, and with limited mechanical facilities.

Much has been written on this subject as may be seen from the bibliography accompanying the paper, but only in the last few years has any great weight been given to the importance of amortisseur windings on salient-pole generators in the suppression of high voltages under short-circuit conditions.

The present paper is an important contribution in that it presents the field experience before and after the application of amortisseur windings, so that a direct comparison can be drawn as to the effectiveness of the addition.

The authors mentioned in the bibliography accompanying the paper the work of Clarke, Weygandt, and Concordia as represented by AIEE paper No. 37-74. In this paper some very important considerations are set forth and while the paper by Clarke, Weygandt, and Concordia is now of common knowledge, a statement of the conclusions of this paper may not be out of order in this discussion. It is stated that the principal determining factor for the magnitude of overvoltages caused by line-to-line short circuits is the ratio $x_q''/x_d''$, of quadrature-axis subtransient reactance to direct-axis subtransient reactance, and that this ratio is a function of the amortisseur characteristic.

The maximum possible overvoltage caused by a line-to-line short circuit on an open-circuited machine is given very closely by the formula

$$e_{max} = 2\,\frac{x_q''}{x_d''} - 1$$

An important point is that the overvoltage may be considerably increased over the value of this equation by terminal capacitance, the worst condition arising when the capacitive reactance is equal to nine times the negative-sequence reactance of the generator.

In the design of an amortisseur winding for salient-pole generators, consideration must be given not only to the design constants of the generator and to the characteristics of the transmission line and the load, but should also take into account the effect of the design of the amortisseur winding on the reactances of the machine.

For the reasons pointed out, it is desirable that where amortisseur windings are to be applied to existing machines that the manufacturer be freely consulted as much valuable data on the design constants of the generators in question is available from this source. Manufacturers will, I am sure, be glad to co-operate on existing machines not having amortisseur windings.

**S. B. Crary** (General Electric Company, Schenectady, N. Y.): This paper is of considerable interest as it shows the results of tests made on the same machine under similar conditions before and after an amortisseur winding was installed. Such a direct comparison is not always possible. These tests indicate the improvement that may be realized by the use of an amortisseur winding, and are in general agreement with the mathematical analyses which have recently been made of this phenomena.

Whether or not to install amortisseur windings in water-wheel generators has been the subject of discussion for a number of years. It has been realized that they are generally beneficial. However, these benefits did not always seem to be sufficiently important to justify the additional expense of their installation. As a result, as stated by the authors, there are many water-wheel generators which do not have amortisseur windings. It seems to be in order briefly to review benefits which are now recognized as being obtained by their use in water-wheel generators.

1. Amortisseur windings are of value in providing additional torque for generators which are automatically synchronized when such synchronization may occur when the machine is out of phase or slightly off system speed, and also in increasing the possibility of pulling back into synchronism in case synchronism is lost following a system disturbance. The amortisseur windings give additional torque besides that provided by the main field winding, which may be quite limited except at a slip very close to synchronous speed even when the discharge resistance is in the circuit, because of the inadvisability of using a high value of discharge resistance.

2. Amortisseur windings reduce hunting which may become a definite problem under certain circuit conditions as they provide positive damping when a machine is operating at light load. This is of particular value when it is desired to operate a water-wheel generator as a synchronous condenser or under the condition of overexcitation with small kilowatt load. The tendency for oscillation is increased when the machine is connected by lines having an appreciable amount of resistance to the power system or load.

3. Amortisseur windings, because of their tendency to damp out the oscillations more quickly, are of some benefit in improving the ability of machines to ride through system disturbances, faults, and switching operations. This gain in stability, however, is small. High-resistance amortisseur windings or a double amortisseur winding having low- and high-resistance windings were at one time proposed. The advantage of the high-resistance winding is that it provides a braking torque during the period in which an unbalanced short circuit is on the system. This torque, to the extent that it loads the generator, is of benefit in increasing the stability limits. However, with quick switching and the need for systems to ride through the more severe three-phase faults, the benefits of a high-resistance winding do not seem to justify the expense of its installation.

4. Amortisseur windings are effective in reducing circuit-breaker recovery-voltage rates. Messrs. Park and Skeats have shown that the rate of rise is a function of the ratio $x_q''/x_d''$.

5. Amortisseur windings are also of benefit in protecting the field winding against current surges in the armature circuit which may be caused by lightning or internal short circuits. The amortisseur winding reduces the induced voltage in the individual field-pole windings and is a factor under these conditions in reducing the field circuit insulation stress.

6. Amortisseur windings are effective in reducing the overvoltages due to unbalanced faults as has been shown recently by two papers, which have analyzed this phenomena, and by the paper under discussion, which has indicated by test the improvement which may be obtained by the use of amortisseur windings.

The reduction of overvoltages due to unbalanced faults is another reason previously not fully recognized why an amortisseur winding should be used in a water-wheel generator. With the effort to coordinate insulation levels and provide proper protection for system equipment, the use of a properly designed amortisseur winding is a step in a direction which will allow further economies and improvements to be made. It now appears that with a fuller recognition of these advantages amortisseur windings will be used more in the future than they have been recently.

We believe that it would be very interesting and worth while if the authors could give information as to the ratio of the quad-

rature to the direct axis reactances before and after installation of the amortisseur windings. If static tests for the $x_q''$ and $x_d''$ could be made, this would be an indication of the effectiveness of the amortisseur windings at Wilson Dam, as the ratio of these reactances is a fair measure of the ability of the amortisseur to reduce the overvoltages. In checking over the data given in the paper, apparently the reactance of the transformer banks (11 and 12) used in the tests was not given. This would be of interest if it were desired to make calculations to check the magnitude of overvoltage obtained in the tests.

**R. B. George:** I wish to acknowledge the fine co-operation we received from the manufacturers during this work, particularly in furnishing generator reactance data and in giving constructive criticism of the proposed design before we started the work of installing the damper windings.

Mr. Bussey's statement concerning how much has been written on this subject is true at the present time, but the most useful contributions for future undertakings were published after our designs were completed. Wagner's paper[3] and Clarke, Weygandt, and Concordia's paper[2] were published after our design was completed. Mr. Wagner also published a series of articles on this subject in the *Electric Journal* during 1938. When my theoretical studies were made, the paper by Doherty and Nickle[1] and Wagner's paper[3] were the only ones I found directly applicable to the problem. Some useful information is contained in references 4 to 8, inclusive, of the bibliography but, since these papers cover different subjects or viewpoints, one should be well acquainted with the technical features of the problem to apply them to this problem.

Mr. Crary's discussion gives a good summary of the uses of damper windings and the benefits to be obtained by installing them.

For the generator without damper windings, the ratio $x_q''/x_d' = 1.825$. After damper windings are added, we use the ratio $x_q''/x_d''$ which is equal to 1.132. Since the ratio of the quadrature-axis reactance to the corresponding direct-axis reactance is a measure of the peak voltage during unbalanced faults, a reduction of 37.97 per cent is indicated. The calculated values of quadrature-axis and direct-axis reactances are given in table III of the paper. No tests were made to measure the various reactances because such tests are expensive and some of them would require precautions to prevent injury to the windings of a generator which had been in operation for nearly 12 years.

The transformer banks were identical and have 0.221 per cent resistance and 9.88 per cent reactance at 65,000 kva base. The constants of the transmission line are 23.4 ohms resistance, 53 ohms reactance, $349 \times 10^6$ mhos total susceptance, length 67 miles, and operating voltage 154 kv.

If studies of combinations of generator, transformer, and lines are made, the inductance corresponding to the negative-sequence reactance should be used at the harmonic frequency being studied. Formulas for various features or combinations may be found in references 1, 2, and 9 of the bibliography.

# Reconditioning of Insulating Oils by Activated Alumina

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THE use of insulating oil in electrical equipment carries with it the problem of prevention of deterioration when the oil is subjected to elevated temperatures in the presence of air. Deterioration may be accelerated by the presence of moisture and organic acid. This condition is found in certain types of transformers and oil-filled bushings.

Since oxidation of oil results in an increased acidity which can be determined by tests, it is possible to gauge the rate of deterioration by making tests at intervals. The degree of deterioration is determined by the weight in milligrams of potassium hydroxide required to neutralize the acidity of one gram of oil. This test has been described by the American Society for Testing Materials as a "Tentative Method of Test for Neutralization Number for Petroleum Products and Lubricants," designation: *D*-188-27-*T*. The neutralization number so obtained is the weight in milligrams of potassium hydroxide to neutralize one gram of oil.

## Effects of Oxidation

After oil has reached a relatively high acidity number the products of oxidation appear as a sludge in the oil. A pasty coating forms over all parts of the equipment which are immersed in oil. The deposit is greater in thickness where there is a marked differential in temperatures between the oil and the immersed surface. The increase in the thickness of the deposit is especially noticeable on water cooling coils. In the case of transformers, the removal of heat from the core to the heat-radiating surface is retarded and the transformer operates at an increasingly higher temperature under a given load condition. In time the transformer must be removed from service and the sludge washed from the core with a high-pressure stream of oil, and the sludge must be removed from the cooling coils or other radiating surfaces.

In oil-filled bushings a number of factors affect the formation of acid and sludge. Means are usually taken to shield the oil in the gauge glass from sunlight by the use of paint or amber glass. Contact of circulating oil with air should be avoided. Heat from sunlight with a higher ambient temperature on transformer locations indicate that transformer bushing oil should have a higher rate of acid formation. The neutralization number obtained by testing the oil in a large number of 150-kv bushings indicated that sludge formation would start in about four years where the bushings were located on transformers, and in about five years where the bushings were located on oil circuit breakers. After the neutralization number reached 0.5, considerable difficulty was experienced in cleaning the bushings free of sludge. Where the bushings were not equipped with a device to prevent the entrance of moisture, a considerable amount of water was found in the oil. Some bushings are now equipped with a device to prevent the entrance of moisture and at the same time circulation of the oil in the body of the bushing does not bring it in contact with the air surface. The principle of the conservator type of transformer is used in this device.

## Control of Oxidation

In recent years the rate of oxidation has been brought under control by the use of two methods in new transformers. One method is the use of the conservator type of transformer, and the other method involves the introduction of nitrogen in the place of air above the surface of the oil.

In several large industrial plants the problem of maintenance of electrical insulating oil in old transformers became acute. About 500,000 kva capacity in both high- and low-voltage transformers were involved in the problem. In 1932 experiments were started with the use of activated alumina both as a desiccating agent and acid adsorption agent in the control of oxidation of oils in steam and

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The development work described in this paper was carried on by the author who acknowledges the valuable contributions of time and ideas by O. H. Pierce.

hydraulic turbines, transformers, and bushings.

## Qualities of Material

Activated alumina is a relatively new type of solid adsorbent and it has been employed as a desiccant for dehydration of gases, vapors, and liquids. In the treatment of oils its selective adsorptive property was found to be very effective for the removal of acid in solution. The method which has proved satisfactory is to contact the oil with activated alumina, after the oil has been treated in a centrifuge or a blotter-paper press to remove the sludge and moisture. A sufficient

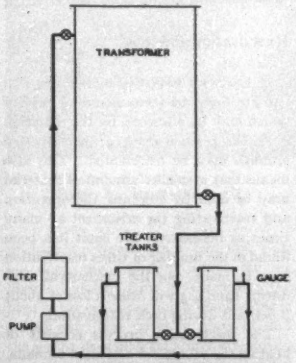



**Figure 1. Schematic diagram of oil treating equipment using open-type tanks**

time-interval contact with the activated alumina is necessary to allow adsorption through the highly porous granules. The material is essentially aluminum oxide, in porous form. It is classed among the commercially pure chemicals. For oil treatment the best results were obtained with grade-A activated alumina in granular form, crushed to 4-8 mesh size. The granules have high strength and resistance to crushing, shock, and abrasion and, therefore, tend to retain their original size and produce a minimum of dust during use. The weight of the packed material is approximately 50 pounds per cubic foot. The size of particles was selected to give a satisfactorily low resistance to flow of oil through the filter bed. The most important problem in developing the material for the maintenance of oil was the reactivation of the material after it had reached its adsorptive capacity. This placed the material on an economic parity with fuller's earth.

Certain advantages and economies accrue to the operating engineer in having a single material which will cover the usual problems encountered in the maintenance of oil. The major requirements may be stated as follows: The removal of moisture and the removal of acidity as formed in the oil contained in oil-filled bushings. The removal of acidity from deteriorated oil. The removal of acidity from reconditioned or new oil by automatic external apparatus or by direct immersion in oil storage tanks or in certain small oil-filled apparatus.

## Method of Use

In large transformers which could not be removed from service for an extended period, the following method of removal of acidity was used. All sludge was removed from the tank and core of the transformer as well as from the oil. After returning the transformer to service, the oil was circulated through a blotter-paper press into a tank filled with activated alumina and thence through an automobile-type filter into the transformer. The tank should be of a closed type if the pump on the filter is used to force the oil through the activated alumina into the transformer. Sludge-free oil may be caused to flow by gravity through the activated alumina into the blotter-paper filter press and pumped directly into the transformer. In this case the tank containing the adsorbent need not be a closed vessel. The oil should be admitted at the bottom and flow upward in order to carry a minimum of dust, although the amount of dust is very small. The open-type tanks used consisted of discarded lightning-arrester tanks. In treating 12 7,000-kva transformers, 150/13.2-kv rating, 1,600 pounds of activated alumina was used, half of the quantity being placed in each tank. Each transformer contained 3,300 gallons of oil. Figure 1 shows a

**Figure 2. Open-type oil treating tanks**

diagram of the arrangement of the equipment, using open tanks. Figure 2 is a photograph of the open-type tanks.

## Quantity of Material

The quantity of activated alumina required for a given amount of oil is based on the condition of the oil and the final neutralization number desired. This may be determined by reference to figure 3. In the foregoing example, the oil had a neutralization number of 0.70. A final neutralization number of 0.10 was desired. The approximate weight of one gallon of oil is 7½ pounds. The weight of 3,300 gallons of oil is 24,750 pounds. Referring to the chart, figure 3, the initial acidity of 0.70 is found and traced vertically to the intersection with the curve marked 0.10 as final acidity and to the

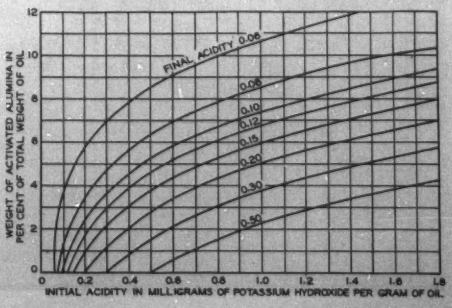



**Figure 3. Chart showing quantity of activated alumina required for oil treatment**

left horizontally where the weight of activated alumina will be found to be 6.3 per cent of the total weight of the oil. Therefore, 1,559 pounds will be required to treat the specified 3,300 gallons of oil. About 60 gallons of oil remained in the activated alumina and was lost during each reactivation.

### Time Required

The length of time required for the correction of acidity varies according to certain conditions. The higher the acidity the faster the correction for a given amount of material. The longer the material is used, between reactivations, the slower becomes the rate of adsorption. It is economical to reactivate the material before reaching the end point. There is a slight slowing up in efficiency of the process on account of low temperatures.

The minimum size of transformer treated was 100 kva. In small transformers the best method is to suspend a canvas bag, filled with activated alumina, inside the transformer. If this is not desirable, the oil may be accumulated and treated in a quiescent state for ten days in a tank containing about one-tenth pound of activated alumina for each pound of oil. The tank may be refilled with oil several times before reaching the capacity of the adsorbent. The maximum time required for treatment of one transformer was eight weeks for a 14,000-kva transformer containing 4,000 gallons of oil. One operator was used, working 40 hours per week, 2,100 pounds of activated alumina were used. (The acidity at the beginning was at neutralization number 0.98 and 0.14 at the end.)

In the treatment of 12 7,000-kva transformers of the type described in the preceding paragraph, one operator worked 40 hours each week for six weeks on each transformer. The oil was circulated at a rate of 7,000 gallons per week or 175 gallons per hour. Rapid circulation does not give a sufficient time for the oil to remain in contact with the material. The acidity was reduced from a neutralization number of 0.70 to 0.10. The rate of correction by weeks follows:

| | |
|---|---|
| First week | 0.70 to 0.46 |
| Second week | 0.46 to 0.34 |
| Third week | 0.34 to 0.22 |
| Fourth week | 0.22 to 0.17 |
| Fifth week | 0.17 to 0.12 |
| Sixth week | 0.12 to 0.10 |

The material was reactivated at the end of the second and fourth weeks in order to gain a slight increase in rate of correction.

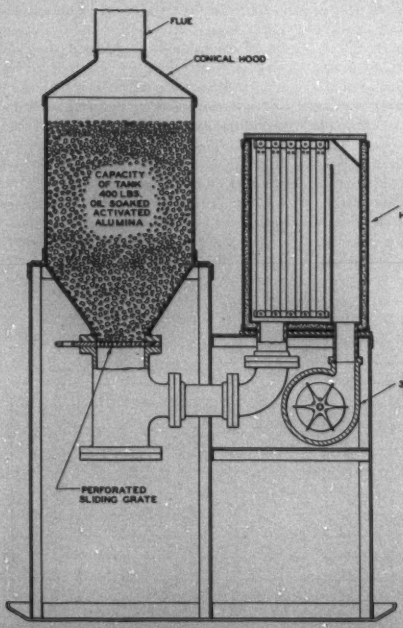

FLUE
CONICAL HOOD
CAPACITY OF TANK 400 LBS. OIL SOAKED ACTIVATED ALUMINA
10 K.W. STRIP HEATER
150 C.F.M. 3600 R.P.M. BLOWER
PERFORATED SLIDING GRATE

Figure 4. Reactivating unit

During the reactivation process, one tank containing 750 pounds of material would be taken out of service with the other tank maintained in operation. After the process slows up, experience indicates that the final reduction may be made automatic by the means of using a thermo-syphon by-pass filter. By the use of the proper quantity of material the acidity may be further reduced or an equally satisfactory condition is to maintain the oil at a reasonably satisfactory level which is believed to be anywhere below a neutralization number of 0.20. In the job described the process was continued two weeks longer than usual because the transformers were being fitted with inert-gas equipment and the automatic equipment was not considered necessary.

### Reactivation Process

It has been indicated that there is a definite limit to the amount of acidity which may be adsorbed by the material. After this point is reached, the activated alumina may be reactivated. This also means that a smaller amount of material may be used by stopping the operation and reactivating the adsorbent as many times as necessary. No limit has been found in the number of times reactivation may be made, but the mechanical wear during handling will cause a loss of about 3 per cent during each reactivation.

The reactivation process consists of heating the oil-soaked activated alumina, in a suitable container, with hot air at 400 degrees Fahrenheit blown through the bed of alumina. When the temperature of the bed exceeds the ignition temperature of the oil, combustion proceeds with air supplied at room temperature until all carbonaceous material is consumed. Control of the draft should be used so that the temperature of the activated alumina does not exceed 1,000 degrees Fahrenheit. Temperatures in excess of 600 degrees Fahrenheit permanently impair the activated alumina for the adsorption of moisture, but do not affect its property of adsorption of acid from oil

### Reactivation Unit

A diagram of the reactivating unit is shown in figure 4. A 3,600-rpm two-inch blower, driven by a one-fourth-horsepower motor delivers 150 cubic feet of air per minute to the heating chamber which contains 10 kw in electric space heaters. A four-inch pipe conducts the air, heated to 400 degrees Fahrenheit, to the base of the tank containing 400 pounds of activated alumina. The opening of the coni-

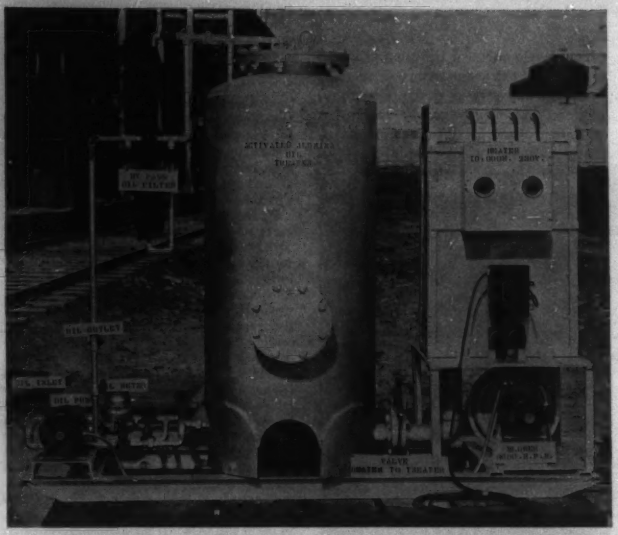


Figure 5. Reactivating unit

cal base is covered with a cast-iron sliding door, perforated to admit the air blast. The tee-fitting is attached to the base of the container and a blank cover is bolted on. This cover is removed and the sliding door or grate above is removed in order to remove the material after reactivation. Figure 5 is a photograph of the combined reactivating and oil treating unit.

## Care of Oil

Consideration has been given to oil which had reached an advanced stage of deterioration. After an oil has been cleaned and the reduction of acidity accomplished, or in the case of new oil, it is desirable to maintain the oil well below the sludging point. In order to do this the transformers have been equipped with a small external tank filled with activated alumina in six-ounce canvas bags. In one group of 14 2,500-kva transformers, the external tank was made from a four-foot section of 10-inch pipe, fitted with flanges at top and bottom. A one-inch diameter pipe connects from the top of this tank to the oil filling connection at the top of the transformer. A similar pipe connects the bottom of this tank to the drain connection on the transformer. The difference of temperature between the top and bottom of the transformer provides a circulation of the oil by thermo-syphon effect. The external tank was charged with 50 pounds of activated alumina which will maintain the 700 gallons of oil contained in the transformer at the original acidity for one year. These transformers are operated at a slight overload continuously and past experience indicates that the neutralization number increases about 0.20 in one year. With a known rate of deterioration and a given quantity of oil, the size of the by-pass unit may be determined for any desired time interval by reference to chart, figure 3. Figure 6 shows a thermo-syphon treater mounted on each of three 333-kva, 13,000/440-volt transformers.

## Oxidation of Treated Oil

Experience with transformers operating with treated oil, dating from 1932 to the present, indicates that none of the old types of oil as well as the new types of oil show an increase in acidity at a faster rate after having the acidity lowered by this treatment. This examination included transformers ranging from 100 kva to 14,000 kva.

## Bushing Oil

More than 75 150-kv bushings have been equipped with a small bag, made of heavy cotton cloth, known as domestic, filled with three pounds of activated alumina. This bag is coiled in the form of a horseshoe in the glass bowl at the top of the bushing. This is the maximum quantity which could be placed in the space available. Experience checks the calculation that this amount of material should keep the oil in original condition for two years. The bags are changed during the regular inspection periods. The use of new material permits the use of water adsorption, in addition to acid adsorption. Experience indicated that all of the water which entered by breather action was adsorbed by the material.

## Transformer Breather

Another serious contamination of transformer oil results from the entrance of water into transformers through the normal breather action caused by changes in temperature. The prevention of entrance of moisture has been studied as a parallel problem to the one of preventing

Figure 6. Thermo-syphon treaters

the ill effects of oxidation. A very practical type of dehydrator was developed with a sight indicator showing the condition of the desiccator in relation to exhaustion of adsorption properties. The design is shown in figure 7, and a photograph of one installation is shown in figure 8. In this installation, the material used was 20 pounds of grade *E*, 8–14 mesh, activated alumina, which is colored by a chemical which is blue when the material is in the dry state. As moisture is adsorbed it gradually fades to a light pink when completely saturated. The physical state of the material does not otherwise change. The material may be reactivated, unless accidentally oil-soaked, by heating in a ventilated electric oven to a temperature of 350 to 600 degrees Fahrenheit until the blue color is restored.

The first transformers to be equipped were five 4,000-kva oil-insulated self-cooled units. At the time of installation,

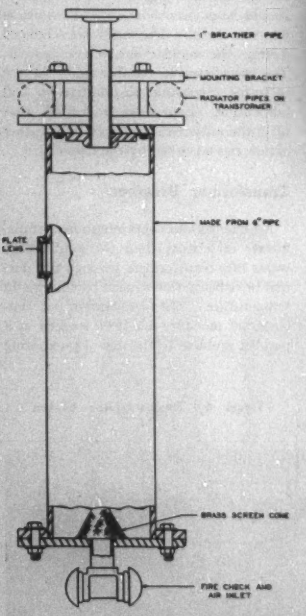



**Figure 7. Transformer breather using activated alumina**

the dielectric test of the oil averaged 22,400 volts. Three months later the average test was 28,800 volts. These transformers previously required filtration of the oil to remove moisture every 12 months.

## Conclusion

The development of the apparatus and methods for the maintenance of oils has given the industry a new approach to a difficult problem which concerns the continuity of service of power equipment. Other materials which have long been

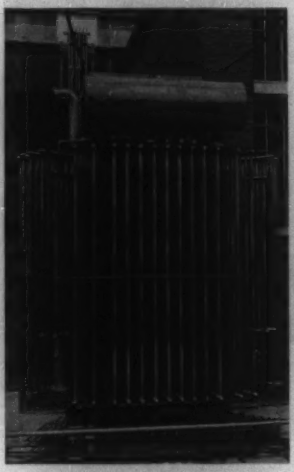


**Figure 8. Transformer breather**

available were restricted to use in central storage and treating plants. Such use is restricted to treatment after considerable deterioration has taken place. A program of preventive maintenance led to the development of apparatus and the selection of a material which would remove acidity as formed in field apparatus. The problem was not considered solved until methods, apparatus, and material were adapted to portable use in any field location. One operator of a semi-skilled type is required only during the initial reconditioning process and the infrequent reactivation of material in automatic filters.

## Discussion

**J. H. Battle** (Memphis Power and Light Company, Memphis, Tenn.): Mr. Housley's paper pertaining to the maintenance of insulating oil is very timely. There is a definite need today for some means of reducing the acidity of insulating oil. Speaking from the power companys' point of view, loads are increasing to the full-load point and even above on equipment that has been in service eight or ten years or longer. The oil in this equipment tends to sludge easily and is difficult to maintain at a reasonable dielectric strength. The sludging causes decreased heat dissipation efficiency. The difficulty in maintaining reasonable dielectric strength causes additional maintenance expense.

As the author points out various means have been devised to slow up the deterioration process. These means may take the form of: reducing the area of oil exposed to the air; keeping moisture, a source of oxygen, out of the oil; or keeping an inert atmosphere above the oil by eliminating the oxygen in the air.

Reducing the area of the oil exposed to the air is accomplished by use of a conservator or expansion tank. Since the oil in the conservator tank gets as hot as the transformer and since on the older transformers this conservator tank is open to the air, the oil in the conservator tank becomes deteriorated. The alternate heating and cooling of the transformer breathes this deteriorated oil into the transformer tank. About a year and a half ago we installed magnetic oil gauges in the conservator tanks of about 19 large power transformers. In all of these conservator tanks we found very bad sludge conditions. Any method to protect the oil in the conservator tank will further protect the oil in the transformer tank. The dehumidifier breather the author describes in his paper will prevent moisture from entering the conservator tank. Thus it will slow up the deterioration process. A more desirable breather would be one that would eliminate the oxygen also.

To us the problem of maintaining in good condition the oil in large conservator-equipped power transformers is not so acute as another problem. That problem is the maintenance of oil in underground distribution transformers. On the Memphis Power and Light Company system the single-phase units range in size from 50 to 150 kva. The three-phase units are 300 kva. Thus each unit contains only a small amount of oil relative to a power transformer but the total of our whole underground system amounts to about 25,000 gallons.

We have found that the dielectric strength of about half this oil becomes unsatisfactory in a year's time. So each spring rather than make dielectric tests on each bank of transformers, we change the oil in the whole underground system. The change is done by means of an electric tank truck. The old oil is pumped out of the transformer, the core and coils flushed off, and reconditioned oil pumped back in. From 1,200 to 1,500 gallons is changed per day.

The old oil is reconditioned by means of a combination centrifuge and blotter press. We have frequently had trouble bringing this oil up to a satisfactory dielectric strength. Sometimes we have found it necessary to run one batch through the machine several times. Acidity tests show that this oil is high in acid. With the end in view of reducing the acidity of this oil, we have experimented with activated alumina. Our outfit consists of two 300-gallon oil tanks equipped with immersion heaters and an alumina tank made from an old water tank 13 inches in diameter and 58 inches high. The tanks are piped so that oil may be transferred from tank to tank through the alumina or circulated through the alumina from one tank. The temperature of the oil is maintained at

about 130 degrees Fahrenheit and is pumped through the alumina at a rate of about 60 gallons an hour. The alumina tank contains about 225 pounds of the chemical. We have found that the alumina does reduce the acidity but it is slow. Our experience is that it takes eight to ten hours to reduce the acidity by $^1/_{10}$ milligram KOH per gram of oil when the acidity is high and longer when the acidity is low. Of course, we could speed up the process by using more alumina but this would increase the cost.

Where it is desired to absorb the acid as it is formed in the oil, alumina answers the purpose very well. The alumina may be placed in bags inside the transformer, oil switch, or storage tanks. The author's method of using an external tank connected to valves at the bottom and top is preferable in the case of transformers in that it does not interfere with the circulation of oil within the transformer.

In the reactivation process it is very desirable that the alumina be handled as little as possible in order to cut down waste and save labor. The best method would be to reactivate the alumina in the same tank the oil is reconditioned in. We would like to ask the author what his experience on this has been.

In conclusion may we repeat that there is a definite need for some method of reducing the acidity of deteriorated insulating oil and Mr. Housley's methods seem to be an answer.

**Frank E. Johnson, Jr.** (New Orleans Public Service, Inc., New Orleans, La.): This paper presents a solution to a problem which has always concerned everyone operating oil-filled transformers. Although the paper treats the subject almost exclusively on the basis of old transformers, it is evident that suitable design features could be incorporated in new transformers to allow the use of this method for the removal of acids and moisture as soon as formed. No doubt transformer manufacturers are cognizant of this, and will provide these facilities as soon as the demand arises.

With reference to the installation of an external tank on a 2,500-kva transformer, mention is made that the neutralization number increased about 0.20 in one year prior to treatment, and that 50 pounds of activated alumina were used for the 700 gallons of oil. Was this rate of increase typical for various sizes and types of transformers investigated? Fifty pounds of activated alumina is about one per cent of the weight of the oil treated. It therefore appears, for the case cited, that one per cent by weight per year would be required for a 0.20 increase in neutralization number. Referring to figure 3, the "initial acidity" figure was evidently about 0.55 prior to treatment, and 0.35 after treatment. Are these values independent of time, that is, could 100 pounds of activated alumina be used with a two-year interval between renewals?

If the weight required is proportional to the time, then another chart can be prepared from figure 3 which will be somewhat easier to interpret for a user desiring to stabilize, or hold his acidity at a given value. The same ordinates can be applied on the chart, but the abscissas can be given as "rate of increase of acidity per year."

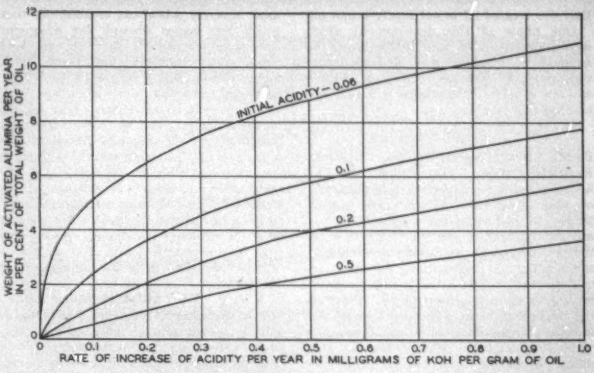



Figure 1

The independent curves then become "initial acidity" curves instead of "final acidity," and it is possible, knowing the rate of increase of acidity, to pick out the necessary quantity of activated alumina to eliminate the acidity increase.

Figure 1 in this discussion illustrates this point.

**T. H. Mawson** (The Commonwealth and Southern Corporation, Birmingham, Ala.): Oil reclamation at the present time is secured by several methods. This paper, by Mr. Housley, gives another method that has additional possibilities. Various schemes providing chemical neutralization with subsequent cleaning of the treated oil to remove the products of this reaction, together with sludge that can exist, will give oil that is satisfactory for reuse.

This particular paper deals with oil that has been used in transformers and bushings. It does not discuss the treatment of oil used in circuit breakers which is subject to considerably different service. Would there be any difference in the treatment of circuit-breaker oil?

In discussing one particular group of transformers which were operating continuously at a slight overload, and which were equipped with thermosiphon treaters, mention is made of an increase of 0.2 per year in neutralization number. If sludge begins to form when the neutralization number reaches 0.4, the full treatment with blotter press and other equipment should be used to reclaim this oil at intervals which depend upon an upper limit of acidity, or sludging, which has been previously determined.

This brings up the point of cost. Costs of reclamation from various sources vary from 3 to 12 cents per gallon for complete reclamation by other methods. For comparison the fixed charges on reclamation equipment plus the direct cost of labor and materials, plus the cost of oil, will determine the value of reclamation and the cheapest method.

The point should also be raised as to the value of reclaiming oil that has shown rapid deterioration when new. Cases on record show that certain oils which have met all of the usual specifications for new oil have not kept these properties for as long a time as other types of oil. After reclamation the same weaknesses appeared. Can any method be used that will make this oil satisfactory?

There are so many points involved on any system that the value of reclamation becomes a problem that is indigenous to that particular system. It must be solved on the basis of over-all costs covering a period of years. This paper gives a possibility of cost reduction, and, with an addition to the present experience of six years of such treatment, it is possible that these costs can be worked out to the satisfaction of all of the interested parties.

**C. F. Hill** (Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.): The paper by Mr. Housley is quite important to many power companies due to the fact the extensive study of apparatus in service has made them conscious of the oil rejuvenation problem.

The author has called attention to one or two rather important advantages of the aluminum oxide, particularly its durability, lack of dusting, and finally, the ease of reactivation.

The statement is made that this new material is competitive with fuller's earth. It would be of considerable interest to have a detailed comparison of these two materials as to rate of reaction with the oil and other factors which control cost.

One statement in this paper does not agree with the usual notion of oil behavior. Normally, it is assumed that removal of the antioxidants by such filtering processes permits more rapid oxidation with further exposure of the oil. Housley states that the rate of oxidation does not speed up—or rather that the acid formation rate does not increase after removal of these acids by activated alumina. The question naturally arises as to the conditions of operation before and after the treatment.

It would also be of interest to know the cost of this reclaiming process per gallon of oil. There has been a considerable doubt if the cost would be reasonable, considering

that the treated oil is not nearly a new oil.

One phase of this development which would appear to be quite attractive is the inclusion of the alumina on the transformer continuously. To keep the oil purified and dry at all times should be very desirable and appears practical.

**F. M. Clark** (General Electric Company, Pittsfield, Mass.): The many problems involved in the satisfactory reconditioning of used transformer oil bear close resemblance to the problems presented in the original refining of the material. Just as the original crude oil can be subjected to too much or too little refining treatment, so can the used oil be subjected to too little or too much reconditioning by means of the adsorbent used. The problem in the original refining of the oil is to remove those materials susceptible to easy oxidation and sludge formation while leaving untouched those original constituents of the oil which act as stabilizers and inhibitors of oxidation. The same problem confronts the application of adsorbents in the reconditioning of used transformer oils. In this case, the undesirable products are those formed as the result of previous oxidation and accompanying chemical change in the oil.

Mr. Housley presents two methods of maintaining transformer oil in suitably good condition during use. The first involves the treatment of the oxidized oil with activated alumina as, for example, by circulation through a bed of the material. Essentially this method is similar to the fuller's earth treatment of oil as a refining step in the original preparation of the material. The second method presented by Mr. Housley involves, during the use of the oil, its continuous gravity circulation through a bed of the activated alumina in accordance with the method of Cox who used fuller's earth in a similar manner.

In both methods of treatment, the objective of Housley appears to be the maintenance of the oil in a condition approaching the original oil color and acidity. It is generally recognized, however, that oil color and oil acidity are properties which in themselves are not safe gauges of sludge formation in transformer oil. Many oils can be obtained with equally low color and of neutral reaction but with widely varying rate of sludge formation in service. In fact, data accumulated indicate that the most severely adsorbent treated oil, that which first comes through the adsorbent bed, possesses the lowest color and is of neutral reaction, yet is characterized by a higher rate of sludge formation than later runnings from the same adsorbent bed, although these latter runnings may possess a much higher color and reaction value. Suitably low oil color and freedom from organic acidity are requisites for a properly treated transformer oil but appear to have no greater significance as a gauge of the sludge-forming properties in reconditioned oil than in the manufacture of the original oil at the refinery.

In his introduction, Mr. Housley states that it is possible to gauge the rate of oil deterioration by a study of the increase in oil acidity. With respect to sludge formation in transformer oil, this statement is only true in a general sense. Dependent on the type of oil and on the degree of refining as well as on the condition of oxidation in transformer use, sludge may form at low or high acid concentration. There appears to be no fixed relation between change in oil acidity and sludge formation in transformer oil which would allow the acidity value to be used as a gauge of the sludging character of the oil. Sludge formation is not a direct result of oil oxidation but appears as the product of a secondary reaction involving the polymerization of products formed in the primary oil oxidation. Among such products are the chemically unsaturated molecules formed as a result of oil oxidation but not capable of evaluation in a test for oil acidity.

Mr. Housley's paper presents no data concerning sludging properties. Sludge formation data are highly desirable and necessary in evaluating the serviceability of reconditioned transformer oils. The relation between the severity of the reconditioning treatment of the oil and the oil sludging tendency should be established. Data available appear to indicate that a used transformer oil, reconditioned by a properly selected and applied treatment with an adsorbent, although possessing many of the properties of a new oil such as low color and neutral reaction, does not possess the high degree of resistance to sludge formation normally associated with new transformer oil. It would be interesting and valuable were Mr. Housley to present data of this type on oils reconditioned by the use of activated alumina.

**J. E. Housley:** The interest shown by those giving discussions is greatly appreciated by the author. This problem of reconditioning insulating oils is certainly an important item on the maintenance program of any power system.

We have had no trouble from sludge in our circuit-breaker oils and in answer to Mr. Mawson's question, we have had no experience in treating these oils.

In the particular group of transformers to which Mr. Mawson refers, the use of a blotter press is avoided by removing the acid as it is formed and thus the oil is maintained below the sludging point. This is accomplished by the use of thermosiphon treaters.

As to the question of cost which has been raised in several of the discussions, it can be said that comparative costs of activated alumina treatment will differ according to local conditions. The cost of treatment per gallon of oil may be expected to range from 2.5 cents to 5.0 cents.

Mr. Johnson, in his discussion, presents an interesting relationship between the weight of activated alumina used and the time of treatment. There is a proportionality existing between the two and the curves, which he presents in his discussion, very clearly show this relationship. On one 2,500-kva transformer, 50 pounds of activated alumina has maintained 700 gallons of oil in good condition for $1^1/_2$ years. At this moment, we do not know how much longer this will maintain the oil. This particular transformer operates at a slight overload continuously.

In response to Mr. Battle's problem, it is suggested that the process of reducing the acid may be speeded up by more frequent reactivations, thus keeping the efficiency of the activated alumina at a maximum. The reactivating unit, shown in figure 5, is used both for treating and reactivating. However, I believe separate reactivation is more desirable, particularly when activated alumina is used to remove acid as formed (thermosiphon treaters) and where the reactivator is required for use on different batches of material.

We cannot answer Mr. Clark's statement regarding acidity and sludge formation specifically, but we have found acidity to be a good criterion of oxidation and sludging in our oils. Our experience has been that oils of fairly low neutralization numbers give no trouble from sludging.

THE CAREFUL INVESTOR JUDGES A SECURITY

BY THE HISTORY OF ITS PERFORMANCE

KERITE

IN THREE-QUARTERS OF A CENTURY OF

CONTINUOUS PRODUCTION HAS ESTABLISHED

A RECORD OF PERFORMANCE

THAT IS UNEQUALLED IN THE HISTORY OF

INSULATED WIRES AND CABLES

THE KERITE INSULATED WIRE & CABLE COMPANY INC

NEW YORK CHICAGO SAN FRANCISCO

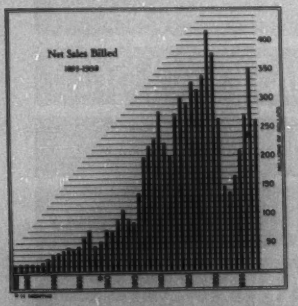
# Industrial Notes

**Large Cable Order to Phelps-Dodge.**—An order has been received from the municipal electric light plant at Jacksonville, Fla., by the Phelps-Dodge Products Corp., New York City, for 133,000 feet of lead covered, paper-insulated cable of 3-conductor design and 750,000 circular mils. The cable is rated for operation at 21,000 volts and is to be installed underground in four parallel circuits, providing a capacity of about 100,000 kw. The cost of the cable is approximately $450,000. The Scofield Engineering Co., of Philadelphia, were the consulting engineers in the extension development of the Jacksonville power system.

**United States Steel Appointment.**—Harvey B. Jordan has been appointed vice-president of the American Steel & Wire Co., a subsidiary of the United States Steel Corporation. Mr. Jordan, who has been in the employ of the wire company for 25 years, will be in charge of operations, and succeeds M. W. Reed, who has been made chief engineer for Carnegie-Illinois Steel Corporation, another U. S. Steel subsidiary.

**Westinghouse At The World's Fair.**—Power and lighting equipment for the New York World's Fair is being supplied in large measure by the Westinghouse Electric & Mfg. Co. Contracts already in execution involve expenditures of over $1,400,000, including the longest and highest electric stairway in America, at the Theme Center, 120 feet long; in addition, the company will have a $1,000,000 exhibit of its own.

**General Electric Sales Gain.**—Orders received by the General Electric Co. for the first two months of 1939 amounted to $51,800,000, compared with $41,300,000 in the same period last year, an increase of 25 per cent. The chart below illustrates the billed sales of the company for each year from 1893 to 1938, inclusive.




**Fansteel Annual Report.**—The annual report of the Fansteel Metallurgical Corp., North Chicago, Ill., recently issued, shows a small profit for the year. A large portion of the company's business is in the field of electrical contacts. While the first 8 months of 1938 showed a loss, increasing operations during the last 4 months enabled a profit to be indicated for the entire year. Continuing profitable business is shown for the first 3 months of 1939. The report contains an article on the widely publicized Fansteel "sitdown" strike litigation, which resulted in a decision by the United States Supreme Court outlawing all such strikes.

# Trade Literature

**Post Insulators.**—Bulletin 673 H, 2 pp. Describes five sizes of station post insulators with voltage ratings of 15, 23, 34.5, 46 and 69 kv. Ohio Brass Co., Mansfield, O.

**Bearings.**—Cat. 390, 72 pp. Describes a comprehensive line of bearings and bushings for general purposes. Includes more than 230 sizes of motor bearings. Price list accompanies the catalog. Johnson Bronze Co., New Castle, Pa.

**Circuit Breaker Panelboards.**—Bulletin 57, 16 pp. Describes "Dublbrak" circuit breaker panelboards and cabinets for lighting and appliance branch circuits. Frank Adam Electric Co., 3650 Windsor Place, St. Louis, Mo.

**Circuit Breakers.**—Bulletin 62, 8 pp. Describes 15-kv and 23-kv oil circuit breakers with motor-wound, spring-actuated control. Installations are illustrated. Pacific Electric Mfg. Corp., 5815 Third St., San Francisco, Calif.

**Heavy Duty Cords.**—Bulletin, 4 pp., "An Engineering Analysis of Super Service Cords and Cables." Includes a sample of the vulcanized rubber jacket of these cords and cables. General Cable Corp., 420 Lexington Ave., New York City.

**Heat Resisting Conductors.**—Catalog 10 E, 64 pp. Describes a wide variety of wires, cables and flexible cords applicable in installations exposed to heat, fire hazard, corrosive fumes, vapors, or oil. Rockbestos Products Corp., New Haven, Conn.

**Nickel Alloy Castings.**—Index, 8 pp., "Nickel in the Brass Foundry." Lists bulletins previously issued pertaining to the use of nickel in castings and results of research work to determine the best practise. International Nickel Co., 67 Wall St., New York City.

**Motors.**—Bulletin 1195, 8 pp. Describes numerous types of squirrel cage induction motors. Included are illustrated construction details and a table giving the common types of squirrel cage motors and their applications. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

**Metal-Clad Switchgear.**—Catalog AE-8-a. Describes metal-clad, oil circuit breaker switchgear for indoor service, available in capacities from 75,000 to 250,000 kva, 5,000 to 15,000 volts, 600 to 2000 amperes. Complete technical data is included. Roller-Smith Co., Bethlehem, Pa.

**Combustion Control.**—Cat. N-01-163, 32 pp. "Metermax Combustion Control for Boiler Furnaces." The application of Metermax combustion control to boiler furnaces of every major type,—pulverized coal-fired, stoker-fired, gas and oil-fired, is described. Leeds & Northrup Co., 4962 Stenton Ave., Philadelphia, Pa.

**Conductivity Bridge.**—Bulletin RC 110, 4 pp. Describes a conductivity bridge, an adaptation of the Wheatstone bridge, for measurement of resistance and electrolytic conductivity. A decade capacitor is also described. Industrial Instruments, Inc., 162 West 23rd St., Bayonne, N. J.

**Cotton Mill Distribution System.**—Bulletin 3901, 8 pp. Describes a recent switchgear installation in a large cotton mill. Outlines in detail a modernized scheme whereby a 25-cycle distribution system was redesigned to accommodate 60-cycle purchased power. I-T-E Circuit Breaker Co., 19th & Hamilton Sts., Philadelphia, Pa.

**Screw Anchor.**—Data Sheet 2-1575. Describes in detail type PX screw anchor, a malleable iron casting, 10-inch diameter and suitable for installation with 5/8- or 3/4-inch anchor rod of required length. Rated holding power 10,000 pounds; tested to 20,000 pounds. Malleable Iron Fittings Co., Branford, Conn.

**Photoelectric Cells.**—Bulletin, 4 pp. Describes "Photronic" cells for industrial and experimental applications. A listing is given of photronic relay equipment used in conjunction with these cells to control chemical processes, water levels, operating signals, alarms, etc. Weston Electrical Instrument Corp., 644 Frelinghuysen Ave., Newark, N. J.

**Circuit Breakers.**—Des. Data 29-080, 4 pp. Describes "De-ion" air circuit breakers primarily intended for circuit protection of main distribution feeders in central stations, industrial plants, or building equipment where heavy concentration of power requires a breaker of 20,000-ampere interrupting capacity. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

**Street Lighting.**—Bulletin 1150, 40 pp. "Advanced Street Lighting Practice." A comprehensive treatment of the fundamentals of illumination, and methods of determining requirements for various types of thoroughfares. Different kinds of refractors used for street lighting are described. Holophane Co., Inc., 342 Madison Ave., New York City.

**Electricity in the Motor Car.**—Booklet, 22 pp., "Electricity and Wheels." A record of electrical progress from the discovery of the magnet, and a review of the part played by electricity and electrical devices in the modern motor car. General Motors Corp., Broadway & 57th St., New York City.

# Born to be *Buried Alive!*

These Parkway Cables are made to give lasting service without exterior protection

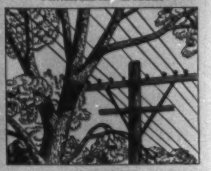
NO ducts, conduits or other external protection are required when installing these Parkway Cables. They may be laid in an ordinary plowed furrow or hand cut trench, and give lasting service at lowest possible cost.

Our non-metallic Amerseal Parkway Cables offer the most economical service and can be used in practically every type of installation. The conductors are sealed in a moisture-proof jacket of tough, resilient rubber, and further protected by an outer covering of asphalted jute. This insulation resists chemical conditions in the soil as well as the effects of moisture and time.

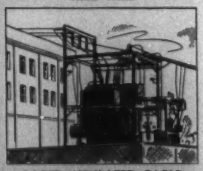
We also manufacture the metallic type of Parkway Cable having a lead sheath and steel-tape armor for more positive protection.

ADEQUATE WIRING SERVES AND SAVES

AMERCLAD CABLES



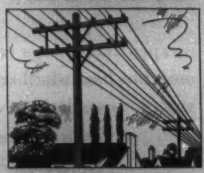
TREE WIRE



PAPER INSULATED CABLE

AMERBESTOS CABLES

VARNISHED CAMBRIC CABLES



RELIANCE WEATHERPROOF WIRES

**AMERICAN STEEL & WIRE COMPANY**

USS

Cleveland, Chicago and New York

Columbia Steel Company, San Francisco, *Pacific Coast Distributors* · United States Steel Products Company, New York, *Export Distributors*

**UNITED STATES STEEL**

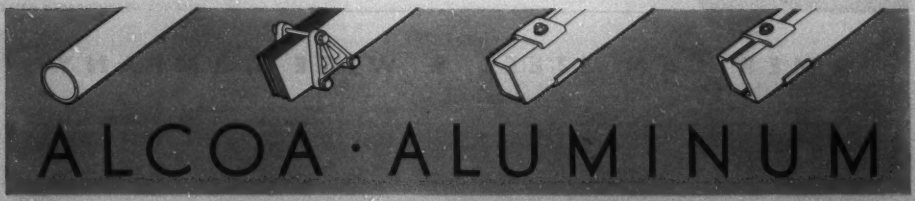
# *Tubular Alcoa Aluminum Bus Bar*

## SIMPLIFIES THE CONSTRUCTION OF OUTDOOR STATIONS

Light in weight, Aluminum bus bar places less burden on supports. They can be few and widely spaced, and the structure itself can be lighter in weight, thereby effecting many economies in materials and labor.

Standard construction methods and simple, inexpensive fittings are used with Alcoa Aluminum bus bar, whether tubular, flats, channels or angles. Installations are attractive. They stay that way, because Aluminum weathers well and stands up under corrosive conditions encountered in most manufacturing processes.

Alcoa Aluminum bus bar offers a high degree of thermal, electrical and mechanical efficiency. Ask our engineers to assist you in selecting the material which best meets your needs. ALUMINUM COMPANY OF AMERICA, 2149 Gulf Building, Pittsburgh, Pennsylvania.



# NETWORK CABLES

RUBBER and BRAID TYPE RS SUPERSHEATH

**General Cable Network Cables are an achievement in the development of higher standards of cable reliability. The all-rubber Supersheath* and the Braided constructions reflect many years of scientific study and experience.**

*Trade-Mark

## GENERAL CABLE

**General Cable Corporation Sales Offices:** ATLANTA • BOSTON • BUFFALO • CHICAGO • CINCINNATI • CLEVELAND • DALLAS • DETROIT KANSAS CITY (MO.) • LOS ANGELES • NEW YORK • PHILADELPHIA • PITTSBURGH • ROME (N. Y.) • ST. LOUIS • SAN FRANCISCO • SEATTLE • WASHINGTON (D. C.)

# New Products

**Shaft Horsepower Meter.**—A new meter developed by General Electric engineers gives accurate and instantaneous measurements of shaft-horsepower and horsepower hours. With the new device the marine

engineer can check the performance of his propulsion equipment over a wide range of speeds, compare the fuel consumption with horsepower-hours output under varying conditions and, in general, can check the efficiencies of boilers and other equipment. Readings can be taken directly from the scale on the dial of the meter, thus eliminating the need for conversion formulas and tables. Consisting essentially of two electric generators, the meter is mounted on the propeller shaft and connected to indicating devices which may be located anywhere. The generator rotors are built in halves and assembled on the shaft after it has been installed in the ship.

**Time Switch.**—A new type S403A timer, applicable where a simple time switching operation is required, has been developed by the Minneapolis-Honeywell Regulator Co., Minneapolis, Minn. It has been designed primarily to control the operation of electrical equipment with a non-inductive load of 10 amperes at 110 volts, 5 amperes at 220 volts, or 1-hp repulsion induction motors; $^1/_3$-hp single-phase or $^1/_4$ hp d-c motors, either 110- or 220-volt ratings. The timer may be manually set to close the circuit and will automatically break the circuit at a predetermined time for any period from one-half hour to eleven hours. A "con-tac-tor" mercury switch is used to make and break the circuit and is of such a design that leveling by sight is sufficient in making the installation.

**Television Transformer.**—A new line of I. F. transformers designed especially for television sound and picture channels, is announced by the F. W. Sickles Co., Springfield, Mass. These transformers are of the perm-trimmed type, thereby permitting maximum gain per unit with desired band width for high definition television. The trap circuits required to eliminate from the picture channel the interference caused by its sound carrier, and also by the adjacent channel sound carrier, are included as part of these transformers. The units measure $3^1/_4$ inches long by 1-inch wide, and $1^5/_{16}$ inches high. Terminals extend from both ends of the shield. The design permits mounting the units under the chassis with above-chassis tuning.

**Wire Wound Control.**—Low power, wire wound controls and rheostats are being introduced by the International Resistance Co., 427 North Broad St., Philadelphia, Pa. These new controls are made in all needed ranges up to 10,000 ohms. They are equipped with the "Silent Spiral Conductor" which provides positive, continuous contact between the rotor arm and end terminal. Power dissipation is 2 watts. The units are available with or without switch and with a complete assortment of shaft variations for any manufacturing or service replacement requirement. Dimensions are $1^1/_4$ inches in diameter by $^9/_{16}$ inch depth of case. Descriptive catalog is available.

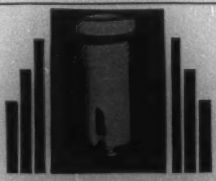
**Frequency Meter.**—The Roller-Smith Co., Bethlehem, Pa., has added to its instrument line a new, type FA, 4-inch square a-c frequency meter, for flush or surface

mounting. Scale length is $3^{13}/_{16}$-inches; accuracy $^1/_4$ of one cycle; voltages 100–125; 125–150; 200–225; 225–250; 55–65 cycles; net weight with reactor, 9 pounds. These instruments are available with or without dial illumination.

**Amber Varnish.**—The outstanding electrical properties of amber are now available in fluid form—an amber varnish, recently introduced by Amber Mines, Inc., 9 Rockefeller Plaza, New York City. Only genuine amber is used in the manufacture of this high voltage insulating varnish, according to the manufacturer. Descriptive literature is available.

**Drafting Cloth.**—A new pencil drafting cloth, known as "Pencil-tex" has been introduced by The Frederick Post Co., P. O. Box 803, Chicago, Ill., which it is claimed may eliminate the use of ink in drafting rooms. Of similar appearance to fine tracing cloth, Pencil-tex has a new and patented velvety surface with a remarkable affinity for pencils of all degrees of hardness. Even the hardest of hard pencils will leave a sharp, uniform, ink-dense line in its wake, according to the manufacturer. This line intensification, together with a glass-like transparency, permits the production of a blueprint with the sharp contrast of prints made from fine ink tracings. A novel sample kit is being distributed without charge to users by the manufacturer and through local dealers.

**Insulating Tape.**—A new combination friction and rubber tape, known as U. S. Twinsulation Tape, and adaptable to all kinds of electrical work, has been introduced by the mechanical goods division, United States Rubber Co., 1790 Broadway, New York City. Due to its high dielectric strength, less of this tape need be applied than is the case with ordinary commercial friction and rubber tape. In fact, in most cases, it is claimed less than half the footage is necessary to make a safe splice; for example, a splice made with two plies of Twinsulation tape will withstand a test current of approximately 12,500 to 15,000 volts.

**You could never guess the importance of this insulator . . .**

This is a porcelain housing for luminous tube signs. An accessory — that has made Neon Signs an industry in itself. An electrode, the contact point between current supply and tubing must fit perfectly in this porcelain protective housing. Dust, dirt, grime and water must be kept out. It's a two fold solution for an important job.

And if you're up against a tough insulator problem—just send the details to Universal. Our engineering department will assist you by furnishing experimental samples.

THE UNIVERSAL CLAY PRODUCTS CO.
1560 E. FIRST ST.
SANDUSKY • OHIO

## *Rugged Bakelite Insulation*

# Tames 90,000 Volts

## *for Diagnostic X-Ray Service!*

MAKERS of diagnostic x-ray equipment cannot afford to take chances with fragile insulation! In their products, super-voltages must be *permanently* tamed for safe use by physicians who may be laymen in the electrical field.

That is why the Kelley-Koett Manufacturing Company adopted impact-resistant Bakelite Molded for the transformer oil container of the Keleket x-ray unit shown here. Located in the tube-head of the device, this part not only supports the heavy transformer, but withstands jars when the head is adjusted. It also safely insulates 90,000-volt conductors molded into its walls.

Your product may require electrical insulation with other special characteristics . . . heat, water and chemical resistance, color or transparency, for example. At Bakelite Plastics headquarters, you'll find a vast variety of dielectric materials to meet these and other requirements.

Get the benefits of "non-shattering" insulation in your designs. Write for Portfolio 33 of reference booklets describing many of these materials . . . consult Bakelite Plastics Headquarters on specific problems.

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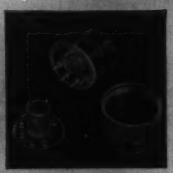
*West Coast:* Electrical Specialty Co., Inc., San Francisco, Los Angeles, Seattle

**BAKELITE**

**PLASTICS HEADQUARTERS**

*A heat-resistant Bakelite Molded handle provides both electrical and thermal insulation in this modern iron.*

*Fuse-tubes of Bakelite Laminated in this automatic fuse-switch stand long service out of doors.*



*Bakelite Polystyrene coil cases and coil forms provide low power-loss in ultra-high frequency radio devices.*

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More than 2000 plastic materials are available at this single, central source . . . phenolic, urea, polystyrene and cellulose-acetate plastics offering wide option of color, dielectric properties and resistance to impact, heat, chemicals and moisture. Supplied in many forms including:

IMPREGNATING VARNISH
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**VISIT THE BAKELITE EXHIBIT, HALL OF INDUSTRIAL SCIENCE, NEW YORK WORLD'S FAIR 1939**

# They wondered why dies wore out so fast...

## ...and found the answer in the STEEL SHEETS!

THIS company recently completed an investigation into the "Bottlenecks" of production. They wanted, naturally enough, to bring manufacturing costs down to an irreducible minimum.

One of the interesting facts which this study brought to light was the disproportionate cost of regrinding and renewing dies. To explain this, they first made a careful check of punch-press practice. Finding no solution here, they next called in an Electrical Sheet Specialist from Carnegie-Illinois. Armed with all the facts of the case, this man speedily located the trouble—in the STEEL. He recommended a change to U·S·S Electrical Steel Sheets, a sample order was placed, and ever since, this manufacturer has been successfully running U·S·S Electrical Sheets.

Latest reports indicate that die life has been increased 50 per cent, and manufacturing cost substantially reduced.

That's the way our Electrical Sheet Service works out in practice. Whenever it's a question of silicon-steel sheets, you can make no mistake by calling in the man from Carnegie-Illinois. That's the surest method of finding a speedy solution to many a tough problem of cost reduction. Call him today.

USS

**ELECTRICAL STEEL SHEETS**

CARNEGIE-ILLINOIS STEEL CORPORATION
*Pittsburgh and Chicago*

Columbia Steel Company, San Francisco, *Pacific Coast Distributors*
Scully Steel Products Company, Chicago, *Warehouse Distributors*
United States Steel Products Company, New York, *Export Distributors*

UNITED STATES STEEL



# Science Abstracts

ALL electrical engineers actively engaged in the practice of their profession should subscribe to "Science Abstracts."

Through "Science Abstracts" engineers are enabled to keep in touch with engineering progress throughout the world, as one hundred and sixty publications, in various languages, are regularly searched and abstracted. "Science Abstracts" are published in two sections, as follows:

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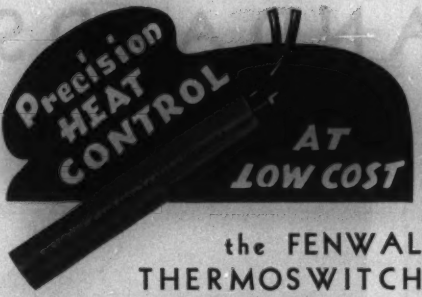
Published monthly by the Institution of Electrical Engineers, London, in association with the Physical Society of London, and with the cooperation of the American Institute of Electrical Engineers, the American Physical Society and the American Electrochemical Society, they constitute an invaluable reference library.

Through special arrangement, members of the A.I.E.E. may subscribe to "Science Abstracts" at the reduced rate of $5.00 for each section, and $10.00 for both. Rates to non-members are $9.00 for each section and $15.00 for both. Subscriptions should start with the January issue. The first volume was issued in 1898. Back numbers are available, and further information regarding these can be obtained upon application to P. F. Rowell, Secy., I. E. E., Savoy Place, Victoria Embankment, London W. C. 2, England.

**American Institute of Electrical Engineers**

A I E E

**33 West 39th Street, New York**




## the FENWAL THERMOSWITCH

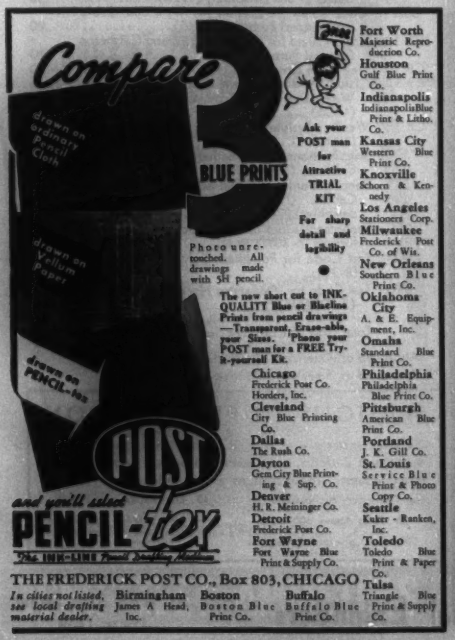
**Compact, rugged, Thermo-responsive electric switch features: 1/10° F. differential, practically no Thermal lag (Brass shell is active element), 200° F. overshoot; unlimited undershoot. Definite, slow, vibrationless break. Range —50° F. to 400° F. Rating 10 Amp. 110V, 5 Amp. 220V. Precise, sturdy, dependable . . . inexpensive.**

**TYPES: Cartridge (illustrated) for bracket mounting or insertion in ½" hole. Immersion with ½" pipe thread head. Block head provides for dial and adjustment knob. Flange head, and for total submersion.**

**Write today on company letterhead for full details or test sample. Sample invoiced subject to full credit in 30 days.**

50 MAIN STREET
ASHLAND MASSACHUSETTS

**Fenwal**
INCORPORATED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BLUE PRINTS
drawn on ordinary Pencil Cloth
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POST
and you'll select
PENCIL-tex
Photo unretouched. All drawings made with 5H pencil.
Ask your POST man for Attractive TRIAL KIT
For sharp detail and legibility
The new short cut to INK-QUALITY Blue or Blackline Prints from pencil drawings—Transparent, Erasable, your Sizes. Phone your POST man for a FREE Try-it-yourself Kit.
Chicago Frederick Post Co.
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Dayton Gem City Blue Printing & Sup. Co.
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Detroit Frederick Post Co.
Fort Wayne Fort Wayne Blue Print & Supply Co.
Fort Worth Majestic Reproduction Co.
Houston Gulf Blue Print Co.
Indianapolis Indianapolis Blue Print & Litho. Co.
Kansas City Western Blue Print Co.
Knoxville Schorn & Kennedy
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Tulsa Triangle Blue Print & Supply Co.

THE FREDERICK POST CO., Box 803, CHICAGO

*In cities not listed, see local drafting material dealer.* Birmingham James A. Head, Inc. Boston Boston Blue Print Co. Buffalo Buffalo Blue Print Co.

## 6 YEARS AGO WE SAID "BETTER POWER RESISTORS COULD BE MADE"

IRC

**Cement Coated POWER WIRE WOUNDS**

## PROVED IT!

**Today—after more than six years of use by leading electrical manufacturers—IRC Cement Coated Wire Wound Resistors have established records of performance, durability and freedom from failure unexcelled in the power resistance field. They dissipate heat rapidly; have extreme mechanical strength; are made to stand heavy overloads, moisture—even the famous salt water immersion test. Danger of expansion of resistance wire or stress on the wire is definitely eliminated by applying the famous IRC Cement Coating at relatively low temperatures.**

**AIRPLANE-SUBMARINE RESISTANCE DEPENDABILITY**

## . . . at No Extra Cost!

**In short, IRC Power Wire Wound Resistors are designed for those who can't afford to take chances on resistor failure . . . yet you pay no extra cost for the extra protection provided by their exclusive Cement Coating.**

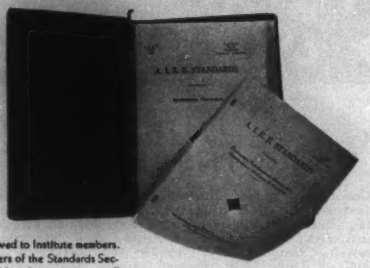
**Write for IRC Catalog IV. Sample resistors gladly submitted to your specifications.**

**INTERNATIONAL RESISTANCE CO.**
**427 N. Broad Street, Philadelphia, Penna.**

*Makers of Resistance Units of More Types, in More Shapes, for More Applications Than Any Other Manufacturer in the World.*

# A.I.E.E. STANDARDS

THE Standards of the American Institute of Electrical Engineers now comprise forty-eight sections on electrical machinery and apparatus. They are chiefly devoted to defining terms, conditions, and limits which characterize behavior, with special reference to acceptance tests, and many of them are recognized officially as American Standards.



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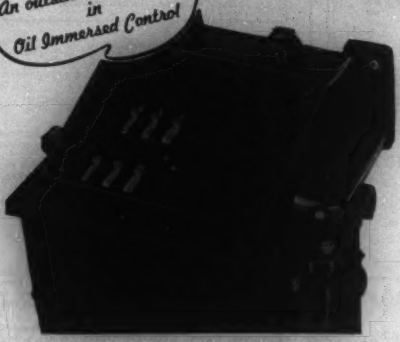

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M.I.T., S.B., S.M., 1932, Elec Engg; 16 mos with Boston Edison Co as co-operative student; 4½ yrs inspection and test on radio transmitters. Location, North preferred. E-431.

B.S., 1935; will obtain E.E., 1939, Newark Col Engg; single, 24. Exper: 2 yrs electronics industries; 2 yrs teaching E.E. subjects. Desires pos above or allied fields. Available about May 1. E-419.

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B.S.E.E., 1936, 23, single. One yr steel mill constr, 1½ yrs pwr station constr, control and relay checker. Desires pos elec util, system protection, planning, oprn. Any elec constr. Knows radio. Location immaterial. E-425.

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B.S.E.E., S. Dak. Mines, 1932, 2 semesters grad study, Univ Mich, 1939, 31, married; exper includes supervision work crews; desires pos illum engr, location immaterial. Avail June 15, 1939. E-427.

B.S. '37, E.E. '38, Princeton; 22, single; specialized in machy; some exper in R.E.A. engg and constr; assoc, Sigma Xi; available immed; will go anywhere, East preferred. E-428.

B.S.E.E., M.A.E.E., '37, Columbia, single, 27; 4 yrs pub util constr, gen wiring; one yr office engr; 2 yrs elec lab asst, Columbia; 9 mos trade sch course. Excellent ref. N.Y., Cal. E-434.

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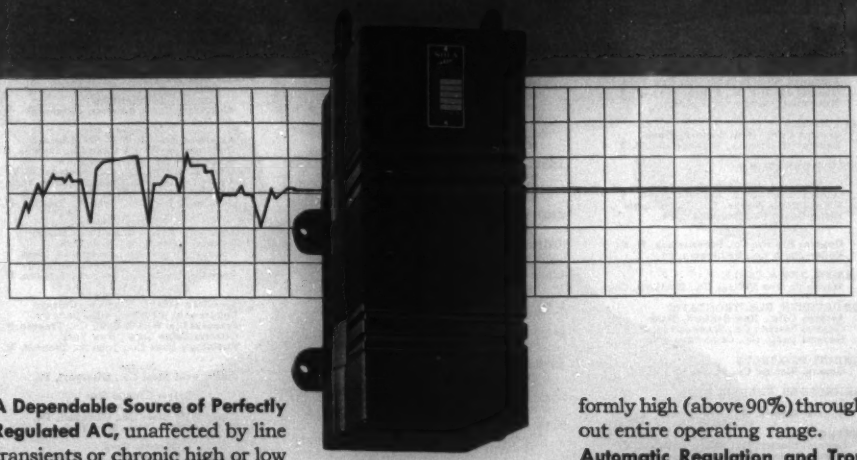

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# INDEX TO ADVERTISERS


| | Page |
|---|---|
| Aluminum Company of America | 8 |
| American Steel & Wire Co | 7 |
| American Tel. & Tel. Co | 19 |
| Bakelite Corporation | 11 |
| Black & Veatch | 16 |
| Burndy Engineering Co., Inc | 15 |
| Carnegie-Illinois Steel Corp | 12 |
| Columbia Electric Mfg. Co | 15 |
| Engineering Directory | 16 |
| Engg. Soc. Employ. Service | 16 |
| Fenwal, Inc | 13 |
| Ferranti Electric, Inc. | 3rd Cover |
| Fowle & Company, Frank F | 16 |
| General Cable Corporation | 9 |
| General Electric Company | 2nd Cover |
| General Radio Company | 4 |
| Giller, Frederick S | 16 |
| Industrial Notes | 6 |
| International Resistance Co | 13 |
| Jackson & Moreland | 16 |
| Kerite Ins. Wire & Cable Co. Inc. | 5 |
| Malleable Iron Fittings Co | 20 |
| Marine Rules | 20 |
| Minerallac Electric Co | 15 |
| New Products | 10 |
| Ohio Brass Company | 1 |
| Okonite Company, The | 4th Cover |
| Polachek, Z. H | 16 |
| Post Co., The Frederick | 13 |
| Roller-Smith Co | 3 |
| Rowan Controller Co | 15 |
| Sanderson & Porter | 16 |
| Sargent & Lundy Inc | 16 |
| Science Abstracts | 12 |
| Southgate, George T | 16 |
| Standards of AIEE | 14 |
| Universal Clay Products Co | 10 |
| United States Steel Corp. Subsidiary | 7, 12 |
| Weston Elec. Instrument Corp | 2 |
| Warren, Howard S | 16 |
| White Engg. Corp., The J. G | 16 |
| Wopat, J. W | 16 |
| Wray & Co., J. G | 16 |

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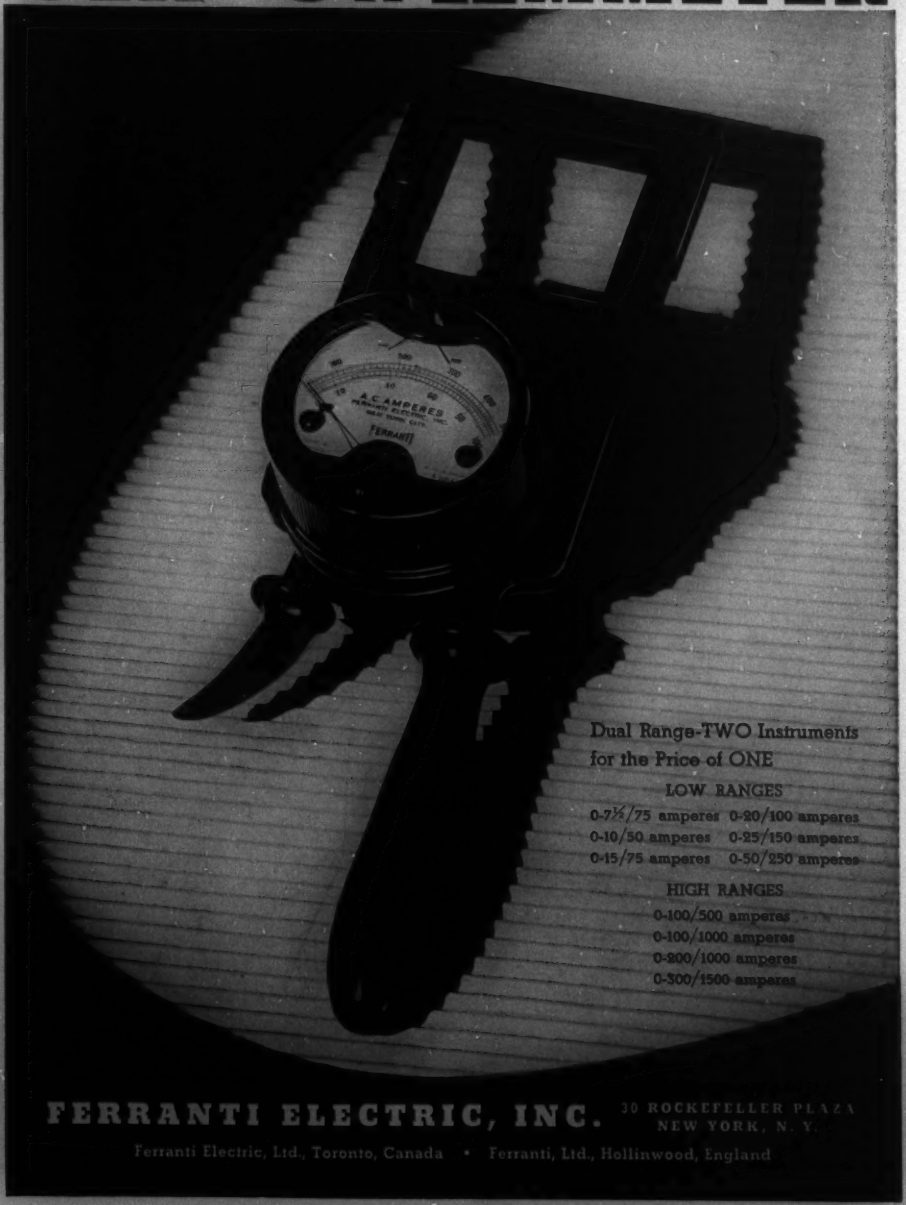


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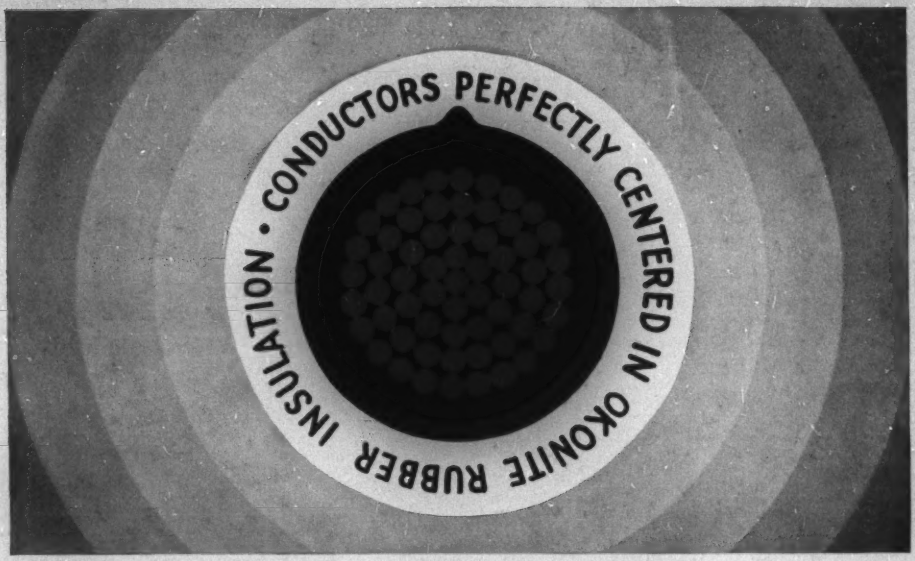


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